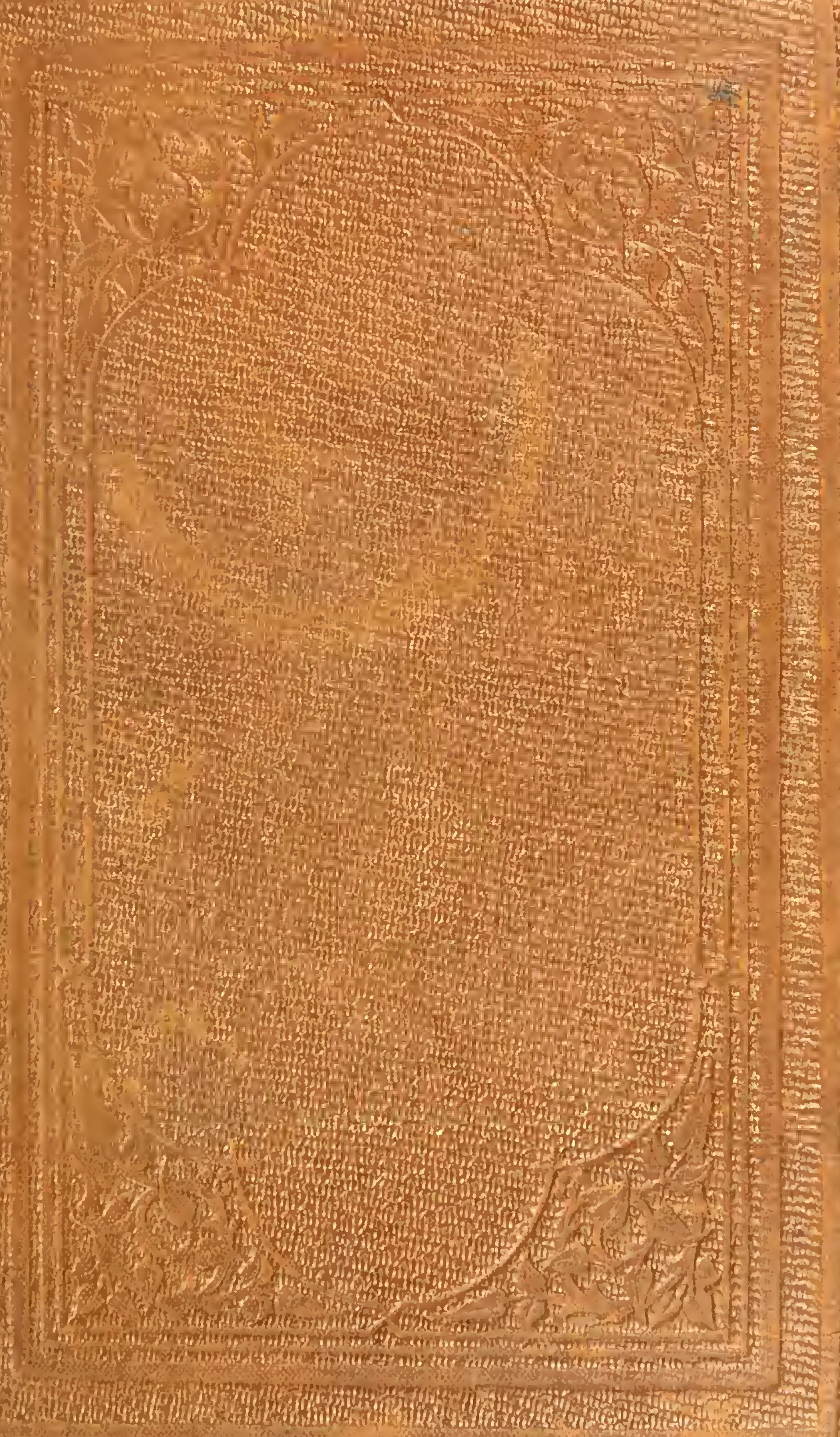

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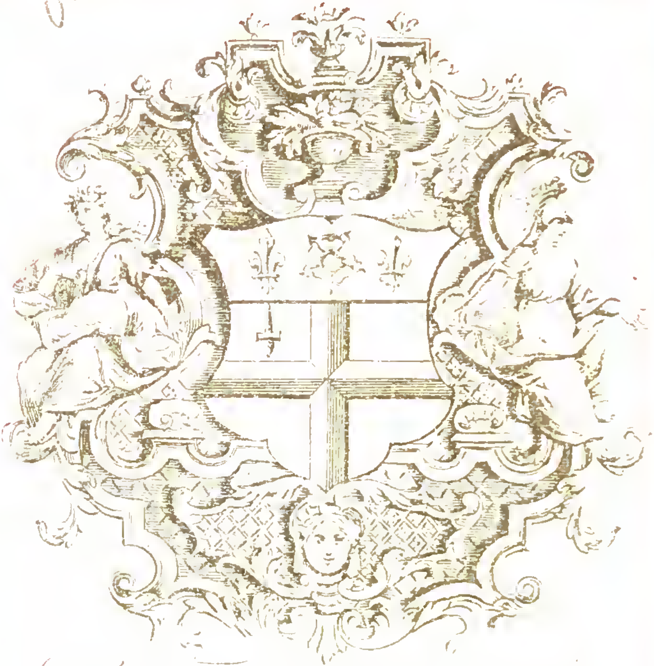

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OUTLINES

OF

PHYSIOLOGY.

BY

JOHN HUGHES BENNETT, M.D., F.R.S.E.,

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PREFACE.

This work is only what it professes to be,—namely, an Outline of Physiological Science. That outline, however, is comprehensive, and embraces the functions of the ultimate tissues and organs of the body in health and disease. Such, it has always appeared to me, is the aspect in which Physiology should be presented to those who desire to connect it with a scientific practice of the medical art. In this point of view, I trust the following pages may be serviceable to many besides those who will receive them as a text-book for the Author's lectures.

JOHN HUGHES BENNETT.

Edinburgh, *November* 1858.

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PHYSIOLOGY.

The word Physiology, derived from φύσις, *nature*, and λόγος, *a discourse*, means literally the doctrine or the history of nature, and, strictly speaking, would comprehend a knowledge of all the physical and natural sciences. But as these in the course of time came to be more particularly studied, they received distinct names,—such as, on the one hand, astronomy, chemistry, and natural philosophy, and on the other, mineralogy, geology, botany, zoology, &c. That science which treats of the functions of living beings, however, still retained the old name, although even now its meaning is every day more and more restricted, as other branches of knowledge become better defined. At present, by physiology is generally understood a knowledge of vital actions in a state of health, as distinguished from pathology (παθος, *disease*), which means a knowledge of the same functions when unhealthy. Again, the modern term histology (ἱστός, a *tissue* or *web*), which is limited to an acquaintance with the functions of the elementary textures of a living body, as distinguished from the study of organs and organisms, also encroaches upon physiology. Thus, vital action, as manifested in the ultimate fibre of a muscle, may be considered histological, as appertaining to elementary structure; vital action as exhibited in a group of muscles, for the purposes of speech, deglutition, respiration, locomotion, and so on, may be called physiological, as belonging to the functions of organs; and vital action in muscle, as shown in perversion of those functions during spasm, convulsion, or paralysis, is more properly called pathological.

It must be evident, however, that these distinctions are altogether arbitrary, and that the three subjects constitute one study. Thus, our knowledge of muscular action is derived from an acquaintance with its ultimate structure and the contraction of its individual fibres, and from an observation of its diseased conditions. Where health terminates and disease begins has never yet been settled; nay, more, what is health to one man would be disease in another, just as the degree of strength which is natural to a delicate frame would be considered weakness in a strong one. Histology, physiology, and pathology, then, are closely allied, and are only different divisions of the same subject; the facts of one are available for the study of all; and any theory deduced from this branch cannot be correct unless in accordance with the data furnished by the others. We shall therefore employ the term physiology in the enlarged sense of comprehending the doctrine of life, whether in health or disease,—which would, perhaps, more properly be denominated biology (*βίος*, *life*),—and avail ourselves of all the knowledge put within our reach by its modern investigators.

THE DOCTRINE OF LIFE IN GENERAL.

In order to understand the general doctrine of life, we must first attend to the characters of the bodies which manifest it. These may be arranged under five heads. All living beings possess,—1. A peculiar arrangement of matter, called *organized*, consisting of a combination of solid and fluid parts, which exercise a reciprocal action on each other.—2. Origin from parents in the form of a germ, which afterwards becomes separated to enjoy an individual existence.—3. The power of taking in from, and giving out substances to, the external world, or what is called assimilation and excretion.—4. The property of passing through certain definite changes, constituting the ages of a living being.—5. Certain derangements from which they may recover, constituting disease. These characters are not possessed by inorganic or brute matter.

Organized or living beings may be further distinguished from inorganized matters, or such as are incapable of living, —1*st*, *By their form.*—An organized being is of a definite form, presenting convex or concave surfaces, and bounded by curved lines. It is of determinate bulk, and invested by a general envelope. Whereas an inorganized body is of indefinite form, or of one presenting flat surfaces bounded by straight lines, such as a crystal. It is of indeterminate bulk, and without any general envelope. 2*d*, *By arrangement of parts.*—An organized being consists of an aggregation of heterogeneous parts, each of which bears a certain relation to the rest. An inorganized body consists of an aggregation of homogeneous parts, no one of which bears any certain relation to the rest. 3*d*, *By the substances of which they are composed.*—An organized being is composed of solid, liquid, and aëriform substances conjointly, constituting the tissues and fluids,—the fluid parts being included within the solid. An inorganized body is composed exclusively of a solid, liquid, or aëriform substance, the particles of which are merely either superimposed upon, or intermingled with, each other. 4*th*, *By their chemical composition.*—An organized being is composed of several elements, associated, at least after the cessation of their vitality, into ternary or quaternary compounds, called *proximate principles*, which, as the result of nutrition, are not capable of being imitated by art, and which are prone to spontaneous decomposition. An inorganized body is composed but of few elements, associated into binary compounds; which are formed by common chemical attraction, are easily imitated artificially, and are not prone to spontaneous decomposition.

The eggs of birds and seeds of plants do not possess all the characters of a living being and yet they live. Once place them in conditions favourable for the development of their existence, and they become transformed into animals or plants. Such bodies are regarded as collections of organic matter possessing dormant vital properties, which, under certain circumstances, waken up and become active.

Numerous efforts have been made to define life. Without entering upon a criticism of these, it may be said that they are all faulty. Most authors have felt the necessity of presupposing some organized structure, the existence of which is taken for granted in their definitions. Bichat says, "Life is the sum total of the functions which resist death;" Treviranus calls it "The constant uniformity of phenomena with diversity of external influences;" Lawrence says it consists "in the assemblage of all the functions or purposes of organized bodies, and in the general result of their exercise;" Duges calls it, "The special activity of organized bodies;" and Béclard, "Organization in action;" which last gives us, as far as a short phrase can, what is understood by life.

With regard to the nature of life itself, two opinions have been held:—1. That life is an independent entity, a vital principle—an idea which has come down to us from the ancients, and is founded on the notion that the union of this principle with the body caused it to live, and its separation to die. 2. That life is the collection of phenomena in organized beings, dependent partly on a certain structure and chemical composition, and partly on the existence of external agencies which stimulate them into action. We do not think it worth while to enter into the long arguments by which both these theories have been supported. It is sufficient to say that the latter is the view which has been adopted by modern physiologists, who believe that the various tissues of an organized body are endowed with various properties, some physical and some vital; that the latter require what are called stimuli to bring them into action; and that a knowledge of the tissues, their properties, their stimuli, and the forces evolved from them, is the true method of arriving at just conclusions concerning life as manifested in health, and as modified by disease. Before, then, we can arrive at a just theory of life in general, we must acquaint ourselves with the structure, chemical composition. and vital properties of the tissues themselves.

PART FIRST.

HISTOLOGICAL PHYSIOLOGY.

Histology comprehends the functions, mode of development, and chemical transformations of the ultimate textures of the body, and has become the recognised basis of our physiological knowledge since the important generalizations of Schleiden and Schwann as to the cell theory were published in 1841. These ultimate or elementary textures are only made visible by means of the achromatic microscope, and have been variously arranged by physiologists. We shall describe them under four heads,—viz., 1*st*, Molecule Tissues; 2*d*, Cell Tissues; 3*d*, Fibre Tissues; and 4*th*, Tube Tissues.

MOLECULE TISSUES.

On examining the different textures under high magnifying powers, we invariably observe a greater or less number of molecules and granules. A molecule is a minute body, presenting optically the appearance of a point or minute dot. A granule is a larger body, in which we can discover a centre and an external ring or margin, which are alternately dark or light according to the focus it is examined with. Molecules may become granules by magnifying them, and granules may appear as molecules by diminishing the magnifying power; so that structurally they are the same bodies. In composition they may be various, consisting of albuminous, fatty, pigmentary, or mineral matter, which may be determined by the action of re-agents. In shape they are usually round, although mineral molecules may be angular or many-sided. They may be isolated and equally diffused, or collected together in groups or masses. In size they may be uniform, but more generally vary from a point scarcely visible up to a magnitude of considerable but varying size, when they are often called globules, as in the milk.

Molecular Fluids.—All fluids in which organization is proceeding, and out of which the higher tissues are formed, are rich in molecules, as may be well seen among plants in the embryonal sac and in the extremity of the pollen tube. The chyle of all animals contains a molecular basis (Gulliver), which gradually becomes cleared up after it has joined the blood, and perfect blood corpuscles are formed. There can be little doubt that the floating molecules enter directly into the substance of nuclei and cell-walls. Molecules are also numerous in the fluid within cells, sometimes being the commencement of new germs, at others the deposits of secreted or effete matter.

Molecular Fibres.—The molecules formed in organic fluids frequently assume a fibrous arrangement. This is well observed in *mucin*, the viscous substance of which frequently exhibits, especially on the addition of acid, a multitude of fibres, composed of molecules aggregated end to end. Similar fibres are formed in the coagulum of blood, the fibres being deposited as molecules, which rapidly assume a fibrous arrangement.

Molecular Membrane.—Albuminous fluids may frequently be observed to contain shreds, which can be spread out into a membrane, and are composed of molecules aggregated closely together. Such membranes may readily be produced artificially by shaking the fluid, adding slight heat, or mixing them with acids or oil. If a fluid drop of oil and another of liquid albumen are brought together, a membrane is immediately produced (*haptogen membrane* of Ascherson). If the two drops are mechanically rubbed together, an emulsion like milk,—containing granules and globules,—is produced; and the latter may readily be shown to be composed of an envelope of this membrane containing a drop of oil. Numerous membranes in the animal body are formed directly by the deposition of albuminous matter, originally in the form of minute molecules, which subsequently melt into a homogeneous layer. Amongst these the substance of cell-walls is perhaps the most important.

Molecular Movements.—All molecules floating in a fluid have distinct movements, which were first described by Robert Brown; hence called Brunonian movements. They may be vibratile, circular, spiral, serpentine, or irregular in character, but seem to be governed by certain laws of attraction and repulsion, which have not yet been minutely investigated. In the interior of cells they frequently pursue certain directions, hence assuming the nature of a circulation, well seen in large vegetable cells. Within the salivary cell they may be seen to move in minute circles, and present a trembling character; in the vibriones so common in putrid fluids, they are vibratory or serpentine.

The Molecular Theory of Organization.

When we consider that all embryonic forms are developed from molecular fluids, and that in adult animals all organizable matter used as food is first reduced to minute molecules, in order that it may become organized, it must be evident that the primary source of vegetable and animal forms must be sought in the molecular element. When, moreover, we know that essentially different fluids, as oil and albumen, when brought into contact, immediately precipitate molecules that assume a globular, fibrinous, or membranous form, and that such a process is facilitated by numerous chemical re-agents, acids, or alkalies, acting on albuminous, fibrinous, or mineral solutions, we readily observe one way in which histological elements may be produced within the body. Such elements, subject to the laws of vitality, may be formative elements (*histogenetic*), whilst others may be retrograde, and give evidence of vital cessation (*histolytic*). Hence the first and last element is, as regards form, the molecular. Organic formative fluids deposit molecules, which arrange themselves, subject to vital laws, into nuclei, cell-walls, and higher textures. These, once produced, subsequently decay in an inverse order, breaking down into individual fragments, and ultimately into minute molecules. During the whole life of an individual organism we observe in it a constant series of these formations and disintegrations—of these histogenetic and histolytic actions. The object of these appears to be the fitting or elaborating, by chemical and histological processes, organic matter in such a way as to perform its appointed office in assimilation or excretion. A knowledge of the vital and physical changes occurring in these molecules, and of the fluids in which they are formed and dissolved, must evidently not only constitute the basis of physiology as a science, but must ultimately form a groundwork for the arts of horticulture, agriculture, and medicine. It is only by the *conjoined* study of histology and organic chemistry that this great work can ever be accomplished.

CELL TISSUES.

When we examine the structures of living beings under high magnifying powers, numerous tissues, but more especially the fluids, the surfaces of membranes, and the various glands, are seen to contain multitudes of minute vesicles or shut sacs, which have received the name of cells. These have long been recognised with the microscope by observers, particularly in plants; but their importance has only been understood since the labours of Schleiden and Schwann (1841) pointed them out as the elementary form of all organisms. They vary greatly in shape, size, and function, a circumstance which necessitates some arrangement of them. We shall divide them into temporary cells and cells of transition,—understanding by the first, cells which do not proceed further in development than the cell form; and by the last, cells which are transformed into more permanent textures. A description of vegetable cells belongs to the science of BOTANY, we shall therefore here confine ourselves to those found in animals, especially such as are highest in the scale.

1. *Chyle and Lymph Cells.*—These are blood-corpuscles in an early stage of development, being, for the most part, free nuclei, only a few having cell-walls around them.

2. *Blood Cells.*—These are of two kinds, coloured and colourless. The coloured cells in fishes, reptiles, and birds are for the most part oval, being largest in reptiles, and smallest in birds. They contain an oval vesicle or nucleus, occupying about a third of their area, which resists the action of acetic acid, while that agent partially dissolves the cell-wall, and destroys the colour. Between the nucleus

and cell-wall is a fluid of a yellowish tint. In mammals, with the exception of the order Camelidæ, in which they are oval, the blood corpuscles present the form of bi-concave circular discs, smallest in the Napu musk-deer, and largest in the elephant. They have no included body or nucleus, and consist of a vesicle containing a coloured fluid. On the addition of water, they swell out so as to become globular, and lose their colour; acetic acid rendering them transparent and almost invisible. In consequence of their shape, they readily become piled upon one another in the form of rouleaux. The colourless cells are globular, having a finely molecular aspect externally, and a distinct nucleus, which, on the addition of acetic acid, usually presents two or three granules. In mammals they are somewhat larger, and in the other vertebrate tribes, smaller than the coloured corpuscles.

The different corpuscles of the blood originate in the chyliferous and lacteal system, and are elaborated as the result of the primary or secondary digestion in the various lymphatic glands. In the lymphatic vessels and thoracic duct they are colourless, but the different stages of their development may readily be observed in chyle, which, in addition to the two kinds of corpuscles previously described, contains a multitude of minute molecules, or what is called a molecular basis of fine fatty particles, communicating to it a milky appearance. The bi-concave disc is fully formed in the chyle, and on joining the venous blood of the jugular vein, is rapidly conveyed through the heart to the lungs, where, coming in contact with the oxygen of the air, its contents become coloured, and communicate its characteristic tinge to the blood. In the fœtus the blood corpuscles are formed in the interior of the cells, which are ultimately changed into vessels, and they are rapidly multiplied by a process of fissiparous development.

The functions of the blood-cells are intimately connected with the exchange of oxygen and carbonic acid continually going on between the blood and atmospheric air in the lungs and in the tissues; but their especial function is the further elaboration and preparation of the *liquor sanguinis*, or fluid part of the blood, in which they swim and are ultimately dissolved. This contains all the elements of nutrition necessary for every part of the organism, as well as the effete matters derived from the wearing away of the tissues. The blood corpuscles, therefore, as the formative cells of the nutritive fluid of the body, must be regarded as the most essential of the constituents of the animal frame.

3. *Nerve or Ganglionic Cells.*—These cells, of various sizes and shapes,—simple, bi-polar, or multi-polar,—are composed of a delicate wall and distinct nucleus, with more or less granular contents. Their function is to form a means of communication between the different nerve tubes, and to evolve that peculiar force which is so essential for carrying on the motor, sensitive, and mental processes of the nervous system.

4. *Adipose Cells* constitute the substance of fats, and secrete in their interior the oily and oleaginous matters so necessary, as we shall subsequently see, for various processes in the economy of all living beings. They are the largest cells in the body, and in shape often polygonal, from the lateral pressure they undergo.

5. *Pigment Cells* present remarkable variations in size and shape, and are so called from their property of forming in their interior, in a fluid or granular form, the various coloured substances which tint the different textures of

plants and animals. This appears to be effected by a species of vital chemistry, which will be subsequently described.

6. *Glandular or Secreting Cells.*—Under this head may be grouped together all those cells, various in form, size, and composition, which have the common function of attracting and selecting from the blood the secretions formed in different glands. Though allied in the performance of this common function, they differ with regard to the nature and amount of the secretion produced, which, so far as can be determined, is not dependent on the structure, chemical composition, or connection with other anatomical elements of the cells themselves. Why some of these cells should secrete bile, others urea, a third class saliva, a fourth milk, and so on, is only explicable by attributing to these minute corpuscles the possession of vital properties, whereby one attracts and selects from the neighbouring blood-vessels the materials which it forms into bile, a second such as it fashions into urea, and so on. No other explanation can be given of a phenomenon which is an ultimate fact in physiology.

7. *The Cells of Transition* are those which, according to the known laws of development, are destined to be transformed into more permanent tissues, in the manner to be hereafter spoken of, and comprehend,—1*st*, Numerous embryonic cells observable in the ovum of plants and animals. 2*d*, Fibre cells; 3*d*, Epithelial cells; 4*th*, Cartilage cells. The great end of these cells is, to be transformed into the tissues formed in various organs, such as blood-vessels, nerve tubes, fibres, membranes, bone, &c.

8. *Pathological Cells.*—In the various morbid growths

which so frequently occur, forming hypertrophies, strictures, tumours, &c., we constantly find an increased number of the same cells we discover in the healthy textures. At other times we find cells which are peculiar to different structural diseases and such as do not occur in health. These may be denominated pathological cells. Among these may be enumerated :—1*st*, *Pus cells*, the formation of which in a fluid constitutes the morbid substances so long known as pus, or purulent matter. 2*d*, *Granule cells*, so called from their containing a number of fatty granules. These may be formed in every kind of normal cell, but occasionally in new cells, as in certain softenings of the cerebral hemispheres. 3*d*, *Cancer cells*, so called from their frequency in cancerous growths. 4*th*, A variety of indefinite corpuscles, the title of which to the denomination of cells is disputed, such as peculiar diaphanous bodies found in various morbid products—tubercle corpuscles, &c.

The Cell Theory of Organization.

A study of the minute bodies to which we have just alluded in plants and animals has led to a generalization or theory, which, although slightly modified since it was originally put forth by Schleiden and Schwann, still remains one of the most important doctrines in biological science. This theory we shall now give as shortly as possible.

All cells originate in a fluid substance, a so-called *blastema* (βλαστος, *germ*), or germ-substance, which, at one time clear, becomes opaque, from the formation or deposition of numerous molecules and granules. Several of these melt together to form a larger body, upon which there is gradually produced a delicate membrane that gradually separates from it, in consequence of the interposition of fluid. After a time, such a corpuscle, or cell, as it is now called, consists of an external envelope or vesicle (*the cell-wall*), the included body upon which it was formed (*the nucleus*), and a fluid between the two (*the cell fluid*). In the nucleus may frequently be observed one or more included granules (*nucleoli*). The changes which subsequently take place in cells thus formed are as follows:—1*st*, Having reached their full development as cells, they gradually dissolve and perish, or the cell-wall bursts, liberating the fluid contents, which constitute a secretion. 2*d*, Various matters may be deposited on the interior of the cell-wall, or in the cell fluid. Thus, albuminous or mineral matter may be deposited which give to certain tissues unusual firmness, as in the fleshy leaves of plants, in the stones of fruit, and in bone; or the fluid may become loaded with albuminous, fatty, pigmentary, or mineral matter, communicating important properties and striking appearances to various tissues. 3*d*, The cell-walls undergo remarkable changes, and by their union with neighbouring cells form complex tissues. Thus, by becoming elongated, and subsequently splitting up, fibres are produced; by becoming elongated and uniting endways to similarly changed cells while the partitions between them disappear, tubes are formed; by throwing out radiating branches, which in like manner unite with others proceeding from neighbouring cells, a net-work or plexus of tubes is produced; and by becoming flattened while their edges adhere together, membranes are developed. In this manner all the elementary textures of a living being may be derived from cells. 4*th*, Many cells have the power of reproduction, or of forming other cells, and this may be accomplished in four different ways,—(1.) By the cell-wall bursting and liberating included germs, each of which gives rise to a cell. (2.) By the nucleus enlarging and dividing into two, each of these into other two, and so multiplying to a certain extent within the original cell-wall; (3.) By the cells themselves dividing into two or more divisions; and (4.) By processes or buds which are thrown out from one part of the cell, and subsequently separate. These four kinds of reproduction from cells may be called the exogenous, the endogenous, the fissiparous, and the gemmiparous modes of redevelopment.

A careful study of the transformations which occur in different cells must convince us that they possess a life peculiar to themselves, and perform special functions. They are born and nourished, and they grow, reach maturity, decline, and die. They are the organs of secretion, as it is in their interior that all the different fluid and solid secretions are elaborated. They are the organs of growth, as they constitute the germs out of which all the tissues are produced. They are the organs of reproduction, not only in causing new growth of tissues, but in multiplying the countless species of plants and animals that we find on the surface of the globe.

In order that cells may carry out these different purposes, they must possess different endowments; whilst some possess the property of storing up in their interior and elaborating various substances to form the secretions, others absorb matters which enable them to build up the different tissues of the organism itself, so as to give it support, ductility, and firmness. A third kind store up pigment, which gives colour to the tissues, or accumulate fat for the purposes of evolution, disintegration, or chemical combustion; and a fourth kind, by a modification of nutritive power, are especially charged with the important office of perpetuating and multiplying new living beings to take the place of those which are worn out and die. So long as all these processes go on harmoniously together, health is preserved.

But the excess or diminution of these cells in particular parts of the economy occasion various kinds of disorders in secretion, nutrition, and reproduction. Lastly, the fluid part of the blood is not unfrequently drawn out of the vessels, and then a new set of cells spring up in it, which, like pus cells, may serve the purpose of getting rid of the morbid products, or, like cancer cells, propagate it in various directions to the destruction of the economy.

The conditions or laws which regulate cell life appear, so far as we are acquainted with them, to be as follows:—1*st*, They must be in a certain relation to a nutritive fluid or *blastema*, from which they can attract and select the various substances necessary to enable them to carry on their respective functions. The most active growing cells are those that swim in such a fluid. In the higher plants and animals the nutritive fluid (sap or blood) is distributed throughout the economy by a series of canals. 2*d*, A certain temperature is necessary to cell life, as it will not proceed below zero or above 145° Fahr. As a general rule, a low temperature checks, whilst an elevated one is favourable to cell growth. 3*d*, Room for expansion is necessary to perfect cell formation. Hence they grow most rapidly and perfectly in fluids or very moist substances; and when they begin to press upon one another, or upon unyielding tissues, their development is checked or destroyed. 4*th*, An appropriate locality has evidently a great influence over cell formation, and this independent of mere temperature and the other circumstances referred to. This is well observed in the reproduction of tissues, the new matter thrown out originating cells, which, as to their ultimate development, are more or less governed by the neighbouring structures. 5*th*, Besides these conditions of a general nature, there is another important one connected with the structure of the cell itself. Thus, if the cell-wall becomes so impregnated with mineral matter that liquids cannot pass through it,—if the cell fluid becomes loaded with albuminous, fatty, or mineral substances, or if the nucleus disappear,—the growth and function of the cell is at once destroyed. Hence the conjoined integrity of the three essential parts of the cell,—viz., cell-wall, cell-fluid, and nucleus, each of which may operate on one another, and on the surrounding blastema, by endosmose and exosmose,—is essential to its activity.

A knowledge of the cell theory as now explained must convince us that the most important vital processes in the economy are essentially connected with the development of the minute corpuscles, which the microscope now enables us to demonstrate and study with the greatest ease. Modern investigation, by its means, has thus completely revolutionized all our previous notions, and proved to us that the cell structures of which we have been speaking are in truth the real agents by which nutrition, secretion, and reproduction are carried on; and by means of which, indirectly, all the animal functions are supported, including even locomotion, sensation, and mental acts. A plant or an animal is in fact a living creature composed of millions of corpuscles, the sum total of the lives of which make up its own. Fat and bone are living tissues, which, in like manner, are composed of as many lives as there are fat and bone cells aggregated together. Pus, that fluid which surgeons have considered as a deposit or secretion foreign to the body, and which ought to be let out as soon as possible, is, like the blood, a living fluid, crowded with multitudes of animal existences, which are born, live, and die, as man himself does. Views of this kind must not only materially modify the notions hitherto attached to the idea of life, but must satisfy us that in all attempts to support, restrain, or prolong it, we can only do so scientifically through our acquaintance with the structures, on the integrity of which it depends. Hence a knowledge of the minute cells in the various organs and tissues of the animal body, the transformations they undergo in health and disease, and the conditions necessary for their existence, and the performance of their functions, is of essential importance to the medical practitioner.

THE FIBRE TISSUES.

A fibre is a solid elongated body, like a thread, and in living beings exists of various degrees of thickness, varying from the $\frac{1}{16000}$th to the $\frac{1}{1400}$th of an inch. What appear to be fibres to the naked eye are in truth bundles of the true fibres, which can only be made visible by means of the microscope. The different kinds of fibres which enter into the tissues are the following :—

1. *Molecular Fibres.*—These are best seen in the decolorized clot of blood, whence they may frequently be observed to form in the field of the microscope by the deposition of minute molecules, which assume a linear arrangement, and subsequently melt together to produce a solid fibre. They vary in thickness from the $\frac{1}{1200}$th to the $\frac{1}{1600}$th of an inch.

2. *White or Areolar Fibres.*—These constitute the areolar or connective textures of the body. They may run in wavy bundles, leaving spaces or areolæ between them, as in the so-called cellular tissue of descriptive anatomists. They may be closer together, and more or less crossed, as in a fibrous aponeurosis, or greatly condensed and running in parallel lines, as in tendon and ligament. Their course may be various and more or less mingled with cells, as in

fibro-cartilage, or fibrous morbid growths. This kind of fibre is formed by the elongation and splitting up of cells. They vary in thickness from the $\frac{1}{1200}$th to the $\frac{1}{8000}$th of an inch.

3. *Yellow or Elastic Fibres.*—This kind of fibre is yellow in colour and highly elastic; hence the names it has received. It is best seen in the *ligamentum nuchæ* of quadrupeds, or in the *ligamenta subflava* of man, extending between the laminæ of the vertebræ. They form the principal bulk of the large arteries, and present under the microscope a curled appearance at their extremities. The fibres may often be seen to anastomose; and are apparently formed from elongation of the nuclei of cells. They vary in thickness from the $\frac{1}{4000}$th to the $\frac{1}{12000}$th of an inch.

4. *Epidermic Fibres.*—This kind of fibre is formed from the splitting up of epidermic cells in various ways, and constitutes the fibrous structure of hair, nail, hoof, horn, feather, quill, and a variety of epidermic appendages. They vary greatly in thickness.

5. *Non-voluntary Contractile Fibres.*—These constitute the so-called muscular coat of hollow viscera, and exist in considerable quantity in the blood-vessels, skin, and iris. Their form is that of ribbon-shaped flattened bands, which are made up of an aggregation of spindle-shaped nucleated cells. They vary greatly in thickness in different textures.

6. *Voluntary Contractile Fibres.*—These constitute the substance of muscle or flesh, the fibrous matter of which may be first divided into solid bundles of fibres, surrounded by a delicate membrane (*sarcolemma*) called the *fasciculus.*

The fasiculi are polygonal, and characterized by transverse lines or striæ, which run across them, consisting of alternate dark and light spaces. Each fasciculus, on being broken up, may be shown to consist of numerous minute fibres or *fibrillæ*, on each of which the same dark and light markings may be seen. The greatest pains have been taken by microscopic observers to determine the ultimate structure of voluntary muscle; but beyond arriving at the fact, that the transverse striæ of the fasciculus are owing to the aggregation of the dark and light markings visible on the minutest fibrillæ, they have not been able to go.

The function of the fibrous tissues is manifold. The white fibrous or connective tissue unites together various structures, especially in the form of tendon, ligament, and aponeurosis. It also offers an elastic medium and support to the frame generally, protecting the blood-vessels and nerves. The yellow elastic tissue performs similar functions; and in addition, in consequence of its great elasticity, serves to restore parts after they have been moved by muscular action; and hence in various places it supplies an antagonist force to muscles. The epidermic fibres are useful as a covering and protection externally, besides forming resisting parts to pressure, and means of offence and defence in numerous animals. The most important property of the fibrous tissues, however, is that of contractility. This exists in different textures, which possess various degrees of power in having it called into activity. Thus, it may be stimulated by cold in the fibres of the bulbs of the hair, but cannot be excited by mechanical irritation or galvanism. In the veins and arteries, on the other hand, cold and mechanical irritation operate, but not galvanism; whereas this agent, with the others, excites contractility in the iris. Lastly, the capillary vessels, in addition to the other stimuli, are influenced by mental emotions, whilst the fibres of flesh are also brought into contraction by the mental act of volition.

Theory of Contractility.

The property of contractility in the fibres of a living being, on the application of a stimulus, is one peculiarly vital, and unlike anything known in physics. It was supposed that the shortening of the fibre was owing to its being thrown into a zig-zag, but it is now known to depend upon its swelling out laterally, and being shortened longitudinally. The property of contractility, however, is not only exerted in such a manner that, by shortening fibres as in muscles, and acting upon the bones and joints, it may induce locomotion. Certain molecular fibres may assume independent motion, as in vibriones, or in the disintegrated molecules of putrid animal or vegetable substances. These bodies, consisting of a fibre more or less long, possess spontaneous movement of a trembling or serpentine character, by which they are propelled through a fluid. Another remarkable movement is seen in the lashing of hair-like processes, shaped like a sabre, which are called cilia, and which cover the mucous surfaces in many parts of the animal body. The peculiar movements of a spermatozoid, in the spermatic fluid, is another example of contractile fibrous motions. In the attached stalk of the vorticellæ, the filament may be seen to assume a spiral form when called into action. Many cells, also, may be seen to enlarge and contract suddenly or slowly, while others contract irregularly, throwing out processes, and thereby continually changing their form, as in the *Amœba.*

The view originally put forth by Haller as to the explanation of contractility was, that it was a vital power inherent in the tissues which possess it; in short, an ultimate fact in physiology; a view which is supported by all that is now known of the subject. It has been maintained, however, by others, that muscular contractility is not so much inherent in muscle as it is dependent on the nervous system. But this opinion is negatived—1*st*, By many ingenious experiments, and especially some by Dr John Reid, who, having removed a portion of the sciatic nerve in a frog, and then exhausted the contractility of the muscles of the limb by powerful repeated galvanic shocks, found that contractility returned after a period of repose; 2*d*, By the observations of isolated fasciculi of muscle under a microscope, which have been seen to contract when entirely separated from nerve; and, 3*d*, By the fact, that individual cells, and even some parts of plants, contract, which have no nerves. The true agency of nerves in muscular parts is not to give them the property of contractility, but to subject it in various ways to the dominion of the acts and feelings of the mind.

THE TUBE TISSUES.

The tubular tissues are distinguished from hollow viscera by their simple structure, and from fibres by their being composed of distinct walls with contents. The principle forms are as follows:—

1. *Air Tubes.*—The structures of plants, and many of the inferior tribes of animals, contain tubes for the transmission of air which are characterized by a deposition in their interior that assumes the form of a spiral; of bars like a ladder (*scalariform*); or of a reticulated or dotted structure. They are formed by the apposition of cells end to end, the partitions disappearing after the deposition of the spiral or reticulated substance on the inner wall of the cell has been

produced. In the higher animals, the air tubes are larger and more complex, terminating in blind expansions or air vesicles.

2. *Blood Tubes.*—In this system we may comprehend the chyle and lymphatic as well as the capillary vessels, which, with the more complex substance of the arteries and veins, constitute the circulatory apparatus in animals. Simple ducts and tubes perform a similar office in plants. The arterial, venous, and lymphatic vessels resemble hollow viscera in having several coats, composed of areolar, elastic, and non-voluntary contractile tissues. The two former are most abundant in the larger vessels, the latter in the smaller arteries. The capillary or minutest blood-vessels are just large enough to enable the blood globules to pass through them in single file. They are composed of a delicate membrane, with nuclei scattered here and there through them, and are formed originally from cells which coalesce with one another by processes or branching prolongations. The smaller arteries and veins are highly contractile; and though it has been much disputed whether the capillaries are so, we have little doubt, from careful observations and measurements, that such is the case.

3. *Dental Tubes.*—These are found in the ivory or dentine, such as occur at an early period in the enamel being filled up by mineral matter to communicate increased density and hardness to that tissue.

4. *Nerve Tubes.*—Nervous matter is principally composed of tubes, which are largest and most symmetrical in the cerebro-spinal nerves, smaller but ampullated in the spinal cord, and smallest of all in the brain, where they gradually diminish in calibre towards the convolutions of the cerebral

hemispheres. The tube itself consists of an extremely delicate membrane externally, inside which is an albuminous layer, constituting the wall of the tube, called the white substance of Schwann, and this contains an oleo-albuminous fluid; in this there may sometimes be seen a slightly fibrous structure, called the band of Remak, or the axis-cylinder of Purkinje. The wall of the tube is characterized optically by possessing a double line, with a clear space in the centre; and on breaking it up, it unites so as to form globules of various sizes, also distinguished by the double outline. The cause of the swellings or ampullæ in the spinal and cerebral tubes has been ascribed to the greater weakness of the investing membrane, and has been supposed to be a *post-mortem* phenomenon. Towards the circumference of the body these tubes terminate in loops. Throughout the body they form numerous connections, through the medium of the nerve cells, with one another, or with various parts of the nervous system. Their mode ef termination in the gray matter of the brain has not yet been traced.

The general function of all the tubular tissues may be said to be that of conduction: the air tubes convey air, the blood tubes distribute the nutritive fluid to all parts of the economy, the dental tubes serve also as nutritive channels, and the nerve tubes conduct the nervous influence.

Theory of Nervous Conduction.

The nerve tubes possess a vital property, named sensibility or excitability, by virtue of which, when irritated, an influence is generated in the irritated or excited part of the nerve tube, and transmitted in certain directions with electric-like velocity. The rapidity with which this is effected negatives the idea that nervous influence travels in the interior of the tube with the contained fluid. It has been supposed that some vibration may be communicated to such fluid; but in fact we are as ignorant of the mode in which the nervous influence travels along a nerve tube as we are of the manner in which galvanism is conducted by a metallic wire. Some nerve tubes only conduct the influence of impressions from the circumference to the nervous centres; others only from the centres towards the circumference. From the circumstance, that some nerves only consist of the former, which, by communicating with the brain, give rise to sensations, they have been called nerves of sensation; whilst such nerves as only consist of the latter, and terminate externally in the muscular system, have been called nerves of motion. Most of the cerebro-spinal nerves, however, are composed of both sets. On tracing a nerve into a ganglion, or a mass of nerve cells, its component tubes separate and pass through it in different directions, in consequence of which an interlacement of them takes place in different directions, and the nerves which emerge from it result from a new combination of tubes, different from those which enter it. The result of this arrangement is, that the impression may be conducted in various ways from one centre or more to another, producing those endless combinations of mental, emotional, sensitive, and motor effects which are produced in the animal frame. These we shall describe more particularly hereafter. In the meantime we may say, that a nerve tube may be excited by psychical or physical causes, the former originating probably in the nerve cells of the brain, the latter from direct pressure or other mechanical causes. As a result of this excitation, a something is generated which, for want of a better term, we call an influence. This influence is then transmitted in various directions, according to the peculiar endowment and anatomical distribution of the tubes excited, occasioning, if they reach the brain, sensation; if the muscles, motion; if the various glands, an increase or diminution of their secretions; and if the blood-vessels, contraction or enlargement of their calibres.

Such are the four great elementary textures of living beings, on the integrity of which are dependent the important vital endowments of growth, contractility, and sensibility. If among these we search for a primary element out of which all the others are evolved, we may place it in some primitive cell, although this, so far as we can determine histologically, is derived from molecular matter, and this in its turn from an organic fluid. An extensive knowledge of the tissues must convince us that the molecule is the primary, as it is the most simple form, and that an aggregation of molecules may even form fibres and membranes without the agency of cells at all. Again, they may combine so as to form nuclei; that is, simple closed vesicles containing a fluid, as in the bi-concave blood-disks of the mammal, which never proceed further in development. Upon nuclei so produced, however, cell-walls may be formed; and as a result of these, the various secretions and textures, as previously explained. Still, the molecule, and not the cell, seems to us to be the primary form; and it would appear, as we shall afterwards see in speaking of reproduction, that the successive elaborations which matter undergoes takes places by successive formations (*histogenetic*) and disintegrations (*histolytic*) of elementary molecules.

But before we can rightly comprehend the philosophy of the formative process, we must attend not only to the form, but to the chemical changes which organic matter undergoes during the successive transformations that take place during the growth and decay of living beings. This leads us to a short discussion of what is known with regard to organic chemistry.

PHYSIOLOGICAL CHEMISTRY.

Of the sixty-two elementary substances known in nature, only twenty are found in organized beings, of which eleven are non-metallic, and nine metallic. The non-metallic elements are oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine, fluorine, iodine, bromine, and silicon. The metallic elements are potassium, sodium, calcium, magnesium, aluminum, iron, manganese, copper, and lead. Of all these, oxygen, hydrogen, carbon, and nitrogen may be regarded as the most essential, and as the basis of all organic matter. Phosphorus enters into the composition of albumen and fibrine, is solidified in the bones in the form of phosphate, and is also found in cerebral substance. Sulphur is necessary to the constitution of albumen, fibrine, and of caseine, and has been found largely in bile. Iron enters into the constitution of the blood. Calcium, in the form of lime, is united with phosphoric and carbonic acids in the skeleton, and in the covering of cretaceous animals. Sodium, in the condition of soda or of common salt, gives alkalinity to the humours and fluidity to the blood. Potassium has similar properties. Chlorine, existing in hydrochloric acid, forms part of the gastric juice; and fluorine has been found in milk and blood. The other substances are only occasional or accidental, and appear to depend upon peculiarities in the kind of food in animals, or soil in vegetables.

According to a beautiful generalization of M. Dumas, an animal should be regarded, in a chemical point of view, as an apparatus of combustion, which incessantly returns to the atmosphere carbonaceous matters in the shape of carbonic acid, hydrogen as a constituent of water, and free azote in the form of oxide of ammonium. In short, from the animal kingdom as a whole there is continually given off carbonic acid, watery vapour, and azote. Vegetables, on the other hand, absorb and fix these substances, retaining the carbon and hydrogen, and setting free the oxygen. They also abstract azote directly from the air, or indirectly from oxide of ammonium or nitric acid. Vegetables for the most part form organic matter under the influence of solar light. They pass ready formed as food into the bodies of animals, which, during their life or after their death, restore them to the atmosphere from which they were originally derived. Thus the animal kingdom is an apparatus of combustion, the vegetable kingdom an apparatus of reduction; the one produces the elements which the other consumes; so that, in the language of Dumas, they are the "offspring of the air." They come from the atmosphere, and return to it again.

The various mineral matters which enter into the constitution of living beings exhibit the same dependence which animals have upon vegetables, and these, again, upon inorganic matter. They simply pass through living beings, as it were, to serve certain important purposes in the scheme of life. Let us take lime and sulphur as examples. Rain water, loaded with the carbonic acid of the air, falls upon calcareous hills, and carbonate of lime, in a state of solution, enters rivers, and is by them carried to the ocean, where it is seized upon by millions of animals, and converted into their external skeletons or shells. The water of rivers and springs also is absorbed by plants and drank by animals; and so lime enters into their substance, and is converted into various salts of that basis, such as oxalates, tartrates, phosphates, &c. Phosphate of lime is the principal element of the bones, besides entering more or less into the constitution of the other tissues of the superior animals, which are continually excreting as well as assimilating it. Lastly, on their death, the lime is dispersed in various ways; even the bones crumble to pieces; and so the mineral returns to the soil from whence it came. Sulphur passes from one region to another in a similar manner, from the sea, which contains sulphur in large quantities, to the atmosphere, thence to the soil, and thence to plants and animals, from whence it again returns to the bosom of the ocean.

These incessant exchanges between the soil or atmosphere, plants and animals, have been laboriously worked out by M. Dumas, and constitute the theory now known as "the chemical balance of organic nature." Liebig, however, has shown that an animal is not the mere consumer of the organic principles elaborated by vegetables. There can be little doubt that, whilst this is done to a great extent, an animal may also produce them; for instance, it can transform, by a vital chemistry of its own, one principle into another, such as albumen into fat, sugar into oil or dextrine, and so on. It is only by a knowledge of this fact we could understand those remarkable degenerations which recent researches have shown us constitute so large a proportion of the organic diseases of man and animals.

The chemical proximate principles which are of such paramount importance in constituting the substance of living beings may be divided into four groups,—namely, 1*st*, The albuminous; 2*d*, The fatty; 3*d*, The pigmentary; and 4*th*, The mineral principles. All these are more or less associated together in every texture and fluid, but some abound in one, and others in another, giving to each peculiar characters.

Albuminous Principles.—These consist of albumen, fibrine, and caseine. Gelatine and chondrine are also allied to this group, although chemically they exhibit some marked differences from the others. Albumen, fibrine, and caseine also contain sulphur, and the two former a minute quantity of phosphorus; otherwise, their relative proportions of carbon, hydrogen, nitrogen, and oxygen are the same. *Albumen* forms the white of eggs, and occurs in large quantity in all the animal fluids that contribute to the nutrition of the organism. It is also found in most of the animal solids, and in nearly every morbid product. *Fibrin* forms nearly the whole substance of the muscles, but exists in small quantity in the blood. *Caseine* constitutes the chief ingredient in the milk of Mammalia. *Gelatine* is obtained by boiling animal membranes, skin, tendon, and bones, which yield a substance that on cooling becomes semi-solid, and if dried, hard and brittle. Common glue and isinglass represent this substance in different degrees of purity. It is apparently formed from the albuminous tissues by the action of boiling. The various albuminous principles now spoken of constitute the basis of the animal frame. They form, when coagulated, the walls of cells and the substance of fibres, tubes, and membranes. In solution, they are for the most part precipitated by acids and by oil, especially albumen; and when recently solidified, are again partially dissolved by acids. The partial solubility of albuminous cell-walls and fibres enables the histologist to detect them with great ease under the microscope.

Fatty Principles.—Fatty matter may exist in living bodies under four conditions,—namely, free, saponified, non-saponifiable, and as a fatty acid. Chemically these consist of carbon, hydrogen, and oxygen, in various proportions; and hence have been called non-nitrogenous substances. In this respect they are analogous to starch, gum, and sugar, from which, apparently, they may be readily formed by a process of deoxidation. There can be no doubt, also, that fat may be produced from albuminous substances by a chemical process of a like nature; for muscles, if rendered inactive in the living body, become fatty, and if after death they be exposed to a stream of running water under certain conditions, they are converted into adipocere.

The healthy growth of the living tissues depends essentially on the union of the albuminous and fatty principles, and the constant chemical exchanges which are apparently taking place between them. The development of a young animal from an egg is a good illustration of this fact. It contains only albumen and a yellow fat with some traces of iron. Yet we see in the process of incubation, during which no foreign matter except atmospheric air can be introduced, that feathers, claws, blood-corpuscles, fibrin, cellular tissue, and vessels are produced. Moreover, the mere union of albumen and oil, under certain conditions, is apparently sufficient to produce those elementary molecules out of which all cells, as well as the molecular constitution of the chyle, are formed. The importance of this fact in nutrition and alimentation will be pointed out hereafter.

Pigmentary Principles.—The various tints communicated to the textures of plants and animals are dependent on two causes. First, the formation of a coloured secretion in the interior of cells, which may present a fluid or granular form, and the exact chemical constitution of which has hitherto been little studied. Secondly, refraction of the rays of light, in consequence of a grooved structure more or less covered with fatty particles, as in the brilliant refracting wing-cases of insects, feathers of birds, and in the tapetum of the choroid membrane. The pigment secretions are evidently allied to the oily constituents in living beings, are more or less dependent on light, heat, and exposure to the atmosphere, and are also influenced by the nature of the soil in vegetables and of food in animals.

Mineral Principles.—These are carried into the body of men and animals, combined with acids, partly in their food and partly in their drink. There they are acted upon in various ways, either by chemical changes induced in them by contact with other salts, but more especially by the oxygen of the atmosphere, which, entering the blood and coming in contact with all the tissues and fluids, is continually forming new affinities and combinations. The most important salts which enter the body are those of lime. Phosphate of lime forms the bulk of the bones and of teeth. Carbonate of lime is more abundant in the fluids and bones of graminivorous than of carnivorous animals. It also constitutes the principal part of the skeleton in the Invertebrata. Both salts enter the economy in the way referred to, become dissolved, and find their way into the blood, and from it are deposited in the organic matrix of bone or cartilage, to give it firmness. Indeed, bones may be regarded as cartilage loaded with phosphate and carbonate of lime. In plants, and some of the lower forms of animals, silicious salts are deposited in like manner, to form a skeleton of the texture. In every case the mineral solution infiltrates a cell structure; so that, on afterwards becoming solid in consequence of the disappearance of the water, an organized form is communicated to mineral matter, as in the silicious epidermis of the grasses, the shells of the Mollusca and Crustacea, and the bones of mammals. During life, the mineral, like the animal constituents, are continually undergoing changes, new particles being deposited from the blood, while the old ones are absorbed and excreted. Hence the mineral substances necessary for the textures must not only exist in aliment, but are constantly found more or less changed in all the secretions and excretions.

The transformation of cartilage into bone offers the best illustration of the physiological importance of the mineral principles. In the embryo and young subject we find that the skeleton is for the most part made up of cartilage or gristle. This is a white elastic substance, composed structurally of nucleated cells embedded in a hyaline matrix. At certain points in embryonic cartilage, called points of ossification, it is observed that the cells arrange themselves sometimes in groups, at others in lines, and that the mineral matter is deposited in the hyaline substance between them. The cells then unite and break down to form spaces, which are filled with organic molecular matter, out of which blood-vessels and fibrous substance are developed. These line the spaces that now receive the name of Haversian canals or cancelli, according to their form, and anastomose with one another. From the blood-vessels so produced there is now constantly poured out material which is developed into nucleated cells, that become impregnated with phosphate of lime, and these, growing from the vascular surface, produce that regular concentric structure of calcified bone-cells, with laminæ and canaliculi, which characterize osseous texture.

GENERAL PROPERTIES OF LIVING BEINGS.

Having now described the elementary forms and chemical constitution of the textures of living beings, and seen that they possess peculiar endowments, we may next inquire into the general properties which they present. On considering the nature of these, we may at once divide them into two classes,—viz., 1*st*, Those which are reducible to the laws of physics; and 2*d*, Those which, in the actual state of science, cannot be so reduced, and which *therefore* we call vital. The history of physiology exhibits a long series of struggles between the physicists and the vitalists, and we must confess that, in proportion as the vital functions have been encroached upon, so science has advanced. Thus the production of animal heat, and the processes of digestion and respiration, though formerly considered to be vital phenomena, are now known for the most part to be chemical. It is of the utmost importance, therefore, to ascertain what are physical and what are vital phenomena in a living body, not only that we may avoid confounding one with the other, but in order that we may know in what manner the vital functions may be best investigated.

Physical Phenomena of Living Beings.—We observe in the various kinds of living beings phenomena altogether physical, but which are essential to its existence: among these may be mentioned elasticity; gravity; hydraulic, optical, acoustic, and chemical phenomena; imbibition; and endosmose. The importance of this last, in a structure composed of membranes through which fluids are continually passing, must be evident. The cells out of which, as we have seen, most of the tissues are formed, present a membrane admirably adapted for the phenomenon of endosmose, and there can be little doubt that it is constantly operating in these bodies. Again, the absorption of fluid from the stomach and intestinal canal through the mucous membrane, and the processes of absorption and exhalation generally, must be connected with endosmose. Living beings are also subjected to the physical influences of caloric, electricity, and light from without, which operate upon them much in the same manner as they act upon matter in general.

Vital Phenomena of Living Beings.—Although many functions in vegetables and animals could not be explained without physics, there are scarcely any which can wholly be accounted for by mechanical or chemical principles, and thus to the most physical act there are peculiarities superadded in living beings which our present knowledge does not enable us to fathom. The properties of growth, of reproduction, of contractility, and of sensibility are so broadly distinct from anything as yet known to be mechanical, electrical, or hydraulic, as at once to evince the existence of something in connection with living beings alone, which we call vital. When, therefore, we employ this term we only mean that it characterizes certain phenomena which in the present state of our knowledge cannot be accounted for by physical science, and which, being found only in living beings, are consequently vital.

Physical and Vital Forces.—In studying the different phenomena, whether physical or vital, physiologists are in the habit of using the term force much in the same manner that it is used by the general cultivators of science: mechanics has its forces, such as that of the lever; chemistry has its forces, like that of affinity; and physical science has its forces, like that of attraction. Physiology has also its forces. It has been supposed that in the same manner as we have physical attractions and repulsions, so we have vital attractions and repulsions. Then we have contractile, nervous, and germinative forces. The idea of force, whether in physics or physiology, as explanatory of phenomena, must be regarded only as theory, as a mental creation, which we employ as a convenient term to satisfy that intense desire of arriving at definite causes which is instinctive in man. On the other hand, it is often employed to express action, which may be demonstrated and often measured. In this sense it is as applicable to the action of a stomach or of a liver as it is to that of an electric telegraph or a steam-engine.

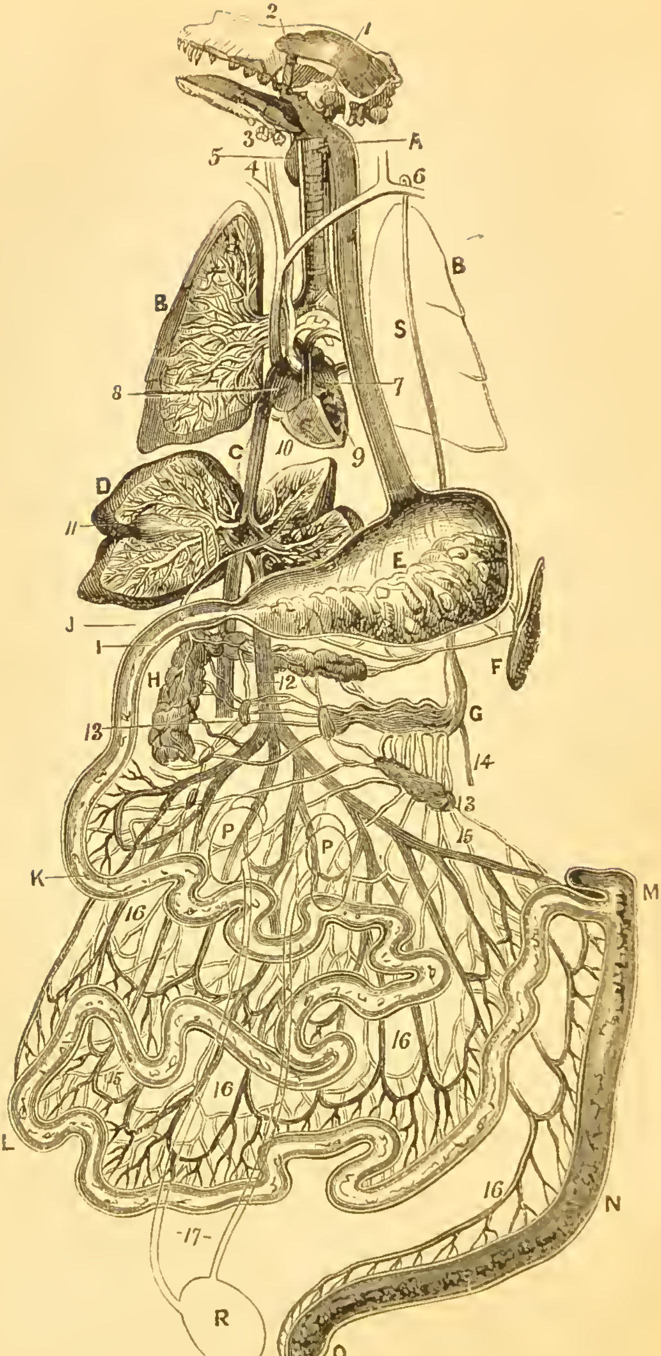
According to Mr Grove, the physical forces are "correlative," or have a relation of mutual dependence, each being capable of producing any one of the rest, either directly or through the medium of some other. Thus, the motion of a body retarded by friction gives rise to heat; and, conversely, heat applied to any form of matter produces its expansion,—that is, motion. The friction of two dissimilar bodies produces not merely heat, but electricity; and heat itself, when made to act on certain combinations of metals, also produces electricity; whilst on the other hand, the electric current may produce heat, light, magnetism, or motion, according to the nature of the substances through which it is transmitted. Light, heat, and electricity, again, are closely related to chemical affinity, which is often specially excited by them, and which can in its turn generate these forces; a material *substratum* being required in both cases. In the same way, as pointed out by Dr Carpenter, there may be a correlation of the vital forces. Thus, as we have seen, the most universal agents of growth are cells. But some of these produce one tissue, and some another, having different vital endowments. Thus, cells converted into muscular tissue, exhibit contractility; those converted into nerve, excitability. Here also a certain substratum or material substance is requisite for the conversion of one force into another. Then, as we have seen, there is a certain relation between the nervous and muscular force: one can call the other into action in a degree proportional to its own excitement; and, again, nervous agency is capable of influencing cell-formation in such a manner as to give rise to the idea that it may be re-converted into the forms of vital force necessary to evolve cells. Again, heat, light, and electricity have long been recognised as excitors or stimuli of the vital forces, and these, operating through a peculiar organized structure, may in fact become vital forces themselves, just as heat becomes electricity when it passes through a certain combination of metals. Thus, vital force may be converted into physical force, and *vice versa*, as when we see one set of cells directed to chemical action, another to mechanical movement, and a third to produce electricity, as in the case of the torpedo, or *Gymnotus electricus*.

It results that the physical and vital forces and properties are intimately united in a living body, and that the activity or life which it exhibits is the sum of those phenomena which we observe in it. When therefore we use the term life, we simply mean that an organized substance is possessed of certain properties partly peculiar or vital, and partly physical, which, when acted upon by appropriate stimuli are competent to give rise to that series of actions in which life consists. We are as ignorant of the true nature of physical as we are of vital properties. It is from the effects alone that we infer their existence. Hence, if one substance exhibits the property of combustibility, it burns; if another, on being stretched, returns to its original size, it is elastic; and if a third presents growth, involving assimilation and excretion, it lives.

PART SECOND.

NORMAL OR HEALTHY PHYSIOLOGY.

Having now ascertained the vital properties and chemical constitution of the elementary textures of the animal body, we have next to describe what is known of the functions of its more complex organs. These have been variously divided by physiologists; but we shall speak of them under three heads,—viz., 1*st*, Function of Nutrition; 2*d*, Function of Innervation; and, 3*d*, Function of Reproduction. The first of these comprehends all those processes called digestion, assimilation, circulation, respiration, absorption, secretion, excretion, &c., which are directed to building up, supporting, and removing the various textures of the body. The function of innervation comprehends those processes connected with locomotion, sensation, and thought or intellect; the third-named function, such as are necessary to the reproduction and development of the animal. The three functions are in the higher animals so mingled together that they are with difficulty separated from one another, although in the lower organisms we find that innervation gradually disappears as we descend in the scale. Notwithstanding this intimate union with, and dependence on, one another, we must study in the first place the laws by which each seems to be governed.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VIEW OF THE NUTRITIVE SYSTEM OF A DOG.

(Modified from Bernard.)

A. Œsophagus.
B. Lungs.
C. Vena Cava.
D. Liver.
E. Stomach.
F. Spleen.
G. Receptaculum Chyli.
H. Pancreas.
I. Duodenum.
J. Entrance of Biliary and Hepatic Ducts.
K. Jejunum.
L. Ileum.
M. Cæcum.
N. Colon.
O. Rectum.
P. Kidneys, with the Super-Renal Capsules above.
R. Urinary Bladder.
S. Thoracic Duct, through which the chyle passes to join the blood.
1. Parotid Gland.
2. Salivary Gland of Nuck.
3. Sub-maxillary and other Salivary Glands.
4. Jugular and Subclavian Veins.
5. Situation of Thymus and Thyroid Glands.
6. Entrance of the Thoracic Duct into the left subclavian vein, near the jugular.
7. Left Auricle.
8. Right Auricle.
9. Left Ventricle.
10. Right Ventricle.
11. Gall Bladder.
12. Vena Portæ, which conveys blood from the intestines to the liver.
13. Mesenteric Glands.
14. Lymphatic Vessels.
15. Lacteal Vessels.
16. Branches of the Portal Vein.
17. Ureters.

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FUNCTION OF NUTRITION.

Instead of treating of nutrition as one of many functions, and especially as only comprehending what refers to the reception and assimilation of alimentary matter, we prefer regarding it as a great compound process, for which many acts are necessary, and all of which combine to keep up the nutrition of the economy. We may consider it as consisting of five stages,—viz., 1*st*, The introduction into the stomach and intestinal canal of appropriate alimentary matters; 2*d*, The formation from these of a nutritive fluid, the blood; and the changes it undergoes in the lungs; 3*d*, Passage of fluid from the blood to be transformed into the tissues; 4*th*, The disappearance of the transformed tissues, and their re-absorption into the blood; 5*th*, The excretion of these effete matters from the body in various forms and by different channels. We believe that it is only by understanding nutrition in this enlarged sense that we can obtain a correct explanation of the dependence of one process upon another, as well as of those important affections which may appropriately be called diseases of nutrition. We shall therefore treat of these stages separately, the whole of which will be more readily comprehended by a study of the diagram (page 48), representing the different parts concerned in the nutritive function of a dog.

STAGE I.—*Introduction into the Stomach and Intestinal Canal of Appropriate Alimentary Matters.*

Aliment.—Food of every variety, when analysed, is resolvable into four elements,—viz., carbon, hydrogen, oxygen, and nitrogen, combined with certain minerals; and we have previously seen that in the great balance of organic nature, whether in the atmosphere, in water, in plants, or in animals, they play the chief part. The chemical constitution of plants and animals is exactly the same; and hence the necessity which modern science has elicited for the food derived from one kingdom of nature being composed of those elementary substances of which the bodies to be nourished in the other kingdom are themselves made up. The proximate principles, however, which contain these may vary under different circumstances, such as a hot or cold climate, or a peculiar constitution of body,—carnivorous or herbivorous, for example. In all cases, however, the demand for food is regulated by the waste of the tissues; hence the processes of growth require constant supply, and this is increased or diminished by the state of the respiration and the amount of bodily or mental exertion,—circumstances which induce loss of force and of texture.

In endeavouring to ascertain what are the best kinds of food requisite for meeting the demands of supply, attention must be paid to the following circumstances:—1*st*, The chemical principles which enter into the constitution of the living being to be nourished; 2*d*, The mode in which these are combined to form tissues and organs; 3*d*, The atmosphere which surrounds it; and 4*th*, The amount of waste produced, as, for instance, amongst men variously employed.

1. With regard to the first point, we have seen that the chemical principles which enter into the constitution of a living being are the albuminous, the fatty, the pigmentary, and the mineral. The pigmentary may here be excluded from consideration, or regarded as a modification of the fatty; so that we may consider, in reference to dietetics, that the essential constituents of the animal frame are the albuminous, the fatty, and the mineral principles. No one

of these groups alone will serve to keep up nutrition in an animal body. They must be all united; a fact which has been clearly demonstrated by numerous experiments of Magendie. He fed dogs upon sugar, oil, gum, or butter alone, and found that for one or two weeks they did very well, but after that, became weak, and died on the thirty-second or thirty-sixth day. When they were fed on white bread and water, they lived fifty days; when on cheese and white of egg, they lived longer, but became feeble, emaciated, and lost their hair. More recent experiments by Edwards and Balzac have shown that a diet of bread and gelatine is insufficient, producing death after emaciation, without appreciable lesion. A little addition of brown soup, however, renders bread and gelatine highly nutritious. Hence it is always necessary to associate a proper mixture of albuminous and fatty principles, in which the mineral enters as a constituent part. Of all the articles of food, human milk appears to be that which contains the three essential substances in the best proportions. A like result may be obtained by mixing other articles together, such as fat pork with veal, potatoes with beef, and rice with mutton or fowl. Again, stuffing is generally added to ham and veal, bacon to beans, ham to fowls, and so on. The addition of butter to bread is the almost universal food of the nursery. Mankind have for the most part adopted these rules instinctively. Persons who feed principally on flesh prefer it fat; and those who live largely on vegetables, as potatoes and rice, take considerable quantities of milk. The same result is obtained by the use of fermented liquors. Hence bread and wine constitute a diet resembling milk in chemical constitution. It is not mere nitrogenous or non-nitrogenous kinds of food, however, that will serve for nourishment, as is theoretically supposed by chemists. To form tissue, these chemical constituents must be converted into albumen and oil, so as to produce those elementary molecules found in the chyle, and which constitute the formative substance out of which nuclei and cells are developed. An unacquaintance with this histological truth has been the cause of much error in dietetics. The mineral elements necessary for nutrition, especially the salts of lime, potash, soda, and iron, constitute the ashes obtained by incineration from all articles of food, and are, as we have previously explained, as essential to the animal frame as the fatty and albuminous constituents.

2. With regard to the manner in which the essential constituents of food are combined to form tissues and organs, we have seen that the three groups of principles are necessary to every texture. There are some, however, which abound in one, and some in another. Thus the fibrous tissues abound in albumen, the glandular organs in fat, and the bones in mineral matter. Whenever fluid albumen and fat are brought in contact with one another, the former is precipitated in a membranous form, and if the two are mingled together by trituration, they assume to the naked eye the appearance of milk or of an emulsion. This is owing to the formation of multitudes of particles such as are found in milk, composed of a delicate vesicle of albumen, containing a minute portion of oil. Such, also, is the invariable structure of all blastemata, or nutritious fluids; and hence the necessity of bringing fluid albumen and oil in contact, —a function performed by the stomach and intestines,—so that by their mixture together a properly constituted molecular basis be produced, out of which texture may be formed.

3. The atmosphere which an individual breathes evidently exercises an important influence on the nature and quantity of the diet. If cold and condensed, there is more oxygen, which will unite with the tissues during respiration, and produce more waste, while greater evaporation

will take place from the surface; a larger supply is therefore necessary, and principally of matter which will rapidly give rise to carbonic acid. Hence the amount of animal and fatty food used by northern nations. In them, also, it will be found that alcohol in all its various forms is used with the greatest freedom,—that is, a non-nitrogenized drink, useful, according to Liebig, as fuel for combustion. In warm countries, on the other hand, where the air is more rarified, a vegetable diet, abounding in sugar and starch, is employed—also non-nitrogenized substances, which, however, being more slow of digestion, are not so readily converted into matter for combustion. Thus, the non-nitrogenous kinds of food, as fat, starch, and sugar, by combination with oxygen, protect the tissues, and produce animal heat. The amount of oxygen in the atmosphere also explains how, with an equal expenditure of force in work, a man requires in summer a less supply of non-nitrogenous food than in winter.

4. The degree of bodily or mental exercise influencing the muscular and nervous textures influences the kind and amount of food. Those who spend their time in either kind of labour require more food than those who pass idle lives. This has been proved experimentally in a variety of ways, and is observable by paying attention to the dietaries of able-bodied men, such as sailors, as compared with those of prisoners and of the sick in hospitals. An able-bodied man requires from 31 to 36 oz. of dry nutritious food daily, of which 26 oz. may be vegetable. In prisons, somewhat less is required, although even there it is not safe to reduce the quantity below 30 oz. daily, as it occasions scurvy.

We can now comprehend some of the more striking phenomena of the modes of life and of respiration in man and animals. Nations of hunters, as well as the carnivorous animals, require a large quantity of fleshy nourishment

In violent corporeal activity they decompose their nitrogenous food into the constituents which serve to be transformed into the tissues on the one hand, and into carbon and hydrogen, to supply respiration, on the other. Hence the unquiet and restlessly active habits of the hunter and of rapacious animals, as well as the extended area for their existence; circumstances which require a scanty population. We meet with the other extreme among the nations which —as in the East Indian races and the Negroes—live wholly on rice, bananas, or similar vegetable substances, in which little nitrogenous matter exists. Hence the enormous quantity which these nations are forced to take in order to extract the necessary amount of actual nourishment for the tissues and for respiration. In this respect they resemble the herbivorous animals who pass most of their lives in a state of nature in feeding and sleeping. In the polar regions, again, we find an immoderate consumption of fat. Here man must produce a greater quantity of heat in order to live, and requires thereto a larger amount of combustible matter or fuel. For this purpose there could be scarcely any substance so applicable as the fat of animals, which principally consists of carbon and hydrogen. Finally, where the breeding of cattle is carried on, we have a transitional state, since man here makes use of the domestic animals to provide himself, in addition to meat, with the substances devoid of nitrogen, in the constituents of milk and the rich fat they furnish, which is almost wholly absent in wild animals. In this manner a skilful agricultural people leads the most judicious life, mingling nutritious substances in the same proportion as nature has mixed it for the suckling in milk, and deriving them from both the vegetable and animal kingdoms. For these generalizations we are indebted to Liebig.

Want of solid aliment produces a peculiar sensation called *hunger*, while want of liquid causes another called *thirst*. These are not so much dependent on a peculiar condition of the stomach or œsophagus as they are upon the general wants of the system. Voyagers in the arctic regions have related numerous instances among the Esquimaux of men who could devour enormous quantities of animal food with impunity; and other cases are known where, from habit, persons have survived on surprisingly small quantities of nourishment. Certain animals, when they are large and fat, fall into a torpid state on the approach of winter, and continue so until the warmth of spring returns. During this period they take no food; their respiration is exceedingly slow; the blood has rather a gentle undulation than a circulation, and the trivial losses which take place are repaired by the gradual absorption of fat. Hence, at the end of the hybernating season, the emaciation of animals subject to its influence is very considerable. Some authentic cases are known of Indian fakirs who have sustained a complete fast, when in a state of trance, for from four to six weeks. Under ordinary circumstances, however, abstinence from food cannot be supported beyond the fourth or fifth day without danger. Young animals generally sink more rapidly than old ones. Of the 150 individuals wrecked in the Medusa, only 15 survived after 13 days of starvation; and some of these had assisted in eating parts of the dead bodies of their companions. One of the most important effects of starvation to attend to is, that after some days it destroys the power of digestion itself to a great extent. Hence the extreme caution necessary in treating such a case. At first only fluids should be given containing little nutriment, the amount of which must be gradually increased.

Mastication.—The food must be properly prepared for the changes it is destined to undergo in the stomach, and to this end it must be broken down by the action of the teeth, jaws, and tongue.

A description of the teeth belongs to anatomy. All that need be said here is, that the incisor, canine, and molar teeth are organs admirably adapted, in man and in the inferior animals, for seizing, lacerating, and grinding various kinds of food. They are fixed in the jaws, which move about in various directions by the action of the muscles. Man having a variety of movements, possesses a very complicated apparatus for this purpose. The tongue continually gathers together the aliment from below the dental arches, and when food is of soft material, assists in crushing it against the palate. To fulfil this function, it not only possesses great mobility, but is endowed with tactile sensibility, whereby we are enabled to judge of the physical qualities and situation of aliment in the mouth, as well as to push it about continually, and appreciate the degree of trituration it undergoes. The lips also being closed, they, with the muscular walls of the cheeks, assist mastication, in keeping the food in the cavity of the mouth, and preventing its accumulation outside the dental arches. As the result of these combined operations, the food is broken down, the utility of which must be obvious. All chemical processes, and the action of solvents, is favoured by division of the matter to be operated on. Too rapid eating is a common cause of indigestion; and considerable masses of food, if not broken by the teeth, pass through the digestive canal unaltered, and deficient nourishment is the result, and this especially if such masses be principally vegetable, or contain the skins of fruits and husks of grain. The nerve principally concerned in all these operations is the motor branch of the fifth pair, and severe injury of it destroys mastication.

Insalivation.—The next process the food is subjected to is a mixture with a peculiar fluid, the saliva. This is a slightly viscid, transparent liquid, which, on standing, deposits a little flocculent sediment, composed principally of the scaly epithelium of the mouth and of the nucleated cells of the salivary glands. (See diagram, 1, 2, and 3.) It contains an organic chemical substance called ptyaline or salivine, on which its peculiar properties are supposed to depend. The food in the mouth constitutes the stimulus for the flow of saliva; and the common expression of the idea of a feast making a man's mouth water shows that the secretion may be excited by mental emotions. Its uses are,—1*st*, By keeping the mouth moist, to favour articulation; 2*d*, To assist in mastication, it being much more difficult to break down dry than moist substances; 3*d*, To facilitate deglutition, as it is impossible to swallow dry matters; 4*th*, To operate upon certain constituents of the food chemically, and although there is great difference of opinion as to how this is accomplished, it is supposed to act more especially on the starchy constituents, readily converting them into glucose or grape sugar; 5*th*, Liebig supposes that, owing to the viscidity of the saliva, air, in the form of froth, is carried to the stomach, and then yields up its oxygen to unite with the tissues.

Deglutition.—The food, reduced to a minute pulp by means of mastication and insalivation, is now carried from the mouth, through the œsophagus or gullet to the stomach (diagram, A). This is accomplished by a rapid contraction of numerous muscular parts, which unite together to produce the desired effect by the agency of a certain series of nerves acting through the spinal cord; hence called *diastaltic* (δια, *through*, στελλω, *to contract*). So long as the bolus of food is contained in the anterior part of the mouth it is under the control of the will, but once pushed back by the pressure of the tongue against the hard palate, to the posterior third of the tongue, it is involuntarily conveyed into the stomach. For this purpose, the lips are closed, to prevent escape of the morsel anteriorly; the soft palate is elevated to prevent its passage into the nasal cavities above; the contraction and backward action of the tongue presses the epiglottis over the larynx, which prevents its going into the windpipe inferiorly; and thus, no other mode of escape being left open, the pressure of the various muscles of the mouth, pharynx, and œsophagus carries it by a continuous wave-like motion from above downwards towards the stomach. The cardiac orifice of the stomach then opens, and it slips through into that viscus.

Digestion in the Stomach.—The stomach is a bag (diagram, E) in which further mechanical and chemical processes are made to operate upon the food, in order to fit it for assimilation or conversion into blood and tissues. The substance of this bag is composed of a serous membrane externally, a muscular coat in its centre, and a mucous layer internally. The muscular coat is composed of three layers of contractile non-voluntary fibre, which closes upon the food, and subjects it to trituration or kneading, whereby the whole of it is intimately mingled together, and mixed with the gastric juice. It is also pushed about in a certain direction, moving along the great curvature from left to right, and then along the lesser curvature from right to left. These motions continue until the entire mass of food is broken down into a fine pulp, called chyme, and passes out of the stomach through the pyloric orifice. The stomach seems to be more irritable during the period of digestion, and its contractility more energetic; so that a stimulus will operate then which will produce no effect in the interval, or when fasting. Hence is explained why, during digestion, the outward orifice is so firmly closed that nothing but the finest pulp passes through it; but this process once over, undigested masses, and even large bodies, such as coins, have been known to go through.

The different motions of the stomach now spoken of have actually been seen to take place in the living human body, in a remarkable case, the study of which has so improved our knowledge of this function that it deserves especial notice. It was that of a young man named St Martin, a Canadian, eighteen years of age, who, when in perfectly good health, was accidentally wounded by the discharge of a musket, on the 6th of June 1822. "The charge," says Dr Beaumont, who describes the case, "consisting of powder and duck-shot, was received in the left side, at the distance of one yard from the muzzle of the gun. The contents entered posteriorly, and in an oblique direction, forward and inward, literally blowing off the integuments and muscles to the size of a man's hand, fracturing and carrying away the anterior half of the sixth rib, fracturing the fifth, lacerating the lower portion of the left lobe of the lung, the diaphragm, and perforating the stomach." From this injury he gradually recovered, but the orifice never closed. When healed, twelve months after the accident, the perforation was two-and-a-half inches in diameter. Subsequently a small fold of the mucous coat of the stomach appeared, which gradually increased till it filled the aperture, and acted as a valve, so as completely to prevent any efflux from within, but to admit of being pushed back by the finger from without. Dr Beaumont, who had carried this difficult case to a successful termination, took the man into his service, and commenced a series of careful observations, which he has embodied in one of the most instructive works extant on the subject of digestion. On placing a solid substance through the opening into the stomach of St Martin, it was seen by Dr Beaumont to be subjected to the movements described.

These movements, however, though useful in perfecting and facilitating digestion, do not constitute the essential part of the process, as was shown by the experiments of Spallanzani, who caused metallic balls to be swallowed, filled with food, which, notwithstanding, was perfectly digested in the stomach. The mucous coat of the organ contains a multitude of follicular glands, that secrete an acid fluid, the gastric juice, which acts as a chemical solvent on the food subjected to it. This is not merely owing to acidity, but to the presence of a peculiar organic substance called pepsine, which is so powerful that one part dissolved in sixty thousand parts of water will digest meat and other alimentary substances. It is poured forth when food reaches the stomach, and is secreted in the tubular glands in the intervals of repose.

The conditions favourable for good digestion in the stomach are,—1*st*, A temperature of about 100° Fahrenheit; 2*d*, Constant movement of the walls of the stomach, which brings in succession every part of the food in contact with the mucous membrane and gastric juice; 3*d*, The removal of such portions as have been fully digested, so that what remains undigested may be brought more completely into contact with the solvent fluid; and 4*th*, A state of softness and minute division of the aliment. Numerous experiments have shown that digestion will go on in gastric juice out of the stomach, but takes three or four times longer a period than when performed by the stomach itself.

According to the experiments of Dr Beaumont upon St Martin's stomach, the rapidity of digestion varies according as the food is more minutely divided, whereby the extent of surface with which the gastric fluid can come in contact with it is proportionally increased. Liquid substances are for the most part absorbed by the vessels of the stomach at once, and any solid matter suspended in them, as in soup, are concentrated into a thicker material before the gastric juice operates upon them. Solid matters are affected so rapidly during health that a full meal, consisting of animal and vegetable substances, may be converted into chyme in about an hour, and the stomach left empty in two hours and a half. Dr Beaumont found that among the substances most quickly digested were rice and tripe, both of which were digested in one hour. Eggs, salmon, trout, apples, and venison were digested in one hour and a half. Tapioca, barley, milk, liver, and fish, in two hours. Turkey, lamb, and pork, in two hours and a half. Beef, mutton, and fowls required from three to three and a half hours, and these were more digestible than veal. These facts were different from what was anticipated, and show that prevailing notions as to the digestibility of different kinds of food are very erroneous. It must be remembered, however, that easy digestibility does not imply high nutritive power. A substance may be nutritious, though so hard as not to be readily broken down; and many soft, easily digested materials may contain a comparatively small amount of nutriment.

Other circumstances besides those referred to affect digestion in the stomach. Among these are,—1*st*, The quantity of food taken: the stomach should be moderately filled, but not distended; 2*d*, The time which has elapsed since the last meal, which should always be long enough for the food of one meal to have completely left the stomach before more is introduced; 3*d*, The amount of exercise previous and subsequent to a meal,—gentle exercise being favourable, and over-exertion injurious to digestion; 4*th*, The state of mind,—tranquillity of temper being apparently essential to a quick and due digestion; *5th*, The bodily health; *6th*, The state of the weather; *7th*, Period of life,—digestion being more active in the young than in the old.

Digestion in the Intestines.—The intestines have been divided into small and large, and each of these subdivided into three portions. Thus the small intestine is divided into duodenum (see diagram, I), jejunum (K), and ileum (L); and the larger intestine into cæcum (M), colon (N), and rectum (O). The whole constitutes a hollow tube, with serous, contractile, and mucous coats, similar, but not identical with those of the stomach. The food operated on in the manner described enters the upper part of this tube, the duodenum, in the form of a thick, grumous fluid called chyme, of a strong, disagreeable acid odour and taste, and containing undigested portions of the food. This is now propelled from above downwards by the action of the contractile fibres of the intestine. As it descends, it is subjected to two kinds of operations,—*1st*, The influence of various fluids with which it is mixed; and *2d*, The gradual absorption of its nutritive substance through the intestinal walls into the system.

Shortly after the chyme has passed out of the stomach it becomes mixed with the bile and the pancreatic juice,—two fluids secreted by the liver and the pancreas, which in man enter the duodenum by a common opening. The exact influence exerted by the bile on the chyme is not known, but it is supposed so to operate as to render the nutritive and excrementitious matter more easily separable. The bile serves other purposes, which will be dwelt on subsequently. The pancreatic juice is a clear alkaline fluid, which has the property, when mingled with a drop of oil, of emulsionizing it with the greatest readiness. Numerous observations and experiments by M. Bernard have shown that it operates with the greatest readiness on the fatty constituents of the food; and that in such animals as have the pancreatic separated from the biliary duct for some distance, as in the rabbit, milky chyle is only formed in the lymphatics after the food has passed the former. Hence there can be little doubt it does emulsionize the fluid fat of the food, and fit it for assimilation. At the same time, recent observations show that this is not its exclusive action, but that it also assists in digesting the other constituents which have escaped the operations of the mouth and stomach. The chyme is also mingled with the fluid of the Brunonian glands of the duodenum, and of the glands of Peyer and Lieberkuhn, scattered over the small intestine generally, but the particular changes these induce in it are not known.

As the chyme passes along the intestinal canal from above downwards, it is squeezed by successive contractions of the tube forcibly against the mucous coat of the intestine. This is covered over with prominences of various forms and lengths, denominated *villi*, which are pendulous folds or projections of the mucous coat itself, so that they present a great extent of surface, over which the chyme passes. The more fluid parts, containing such portions of the food as have been reduced to excessive fineness, now pass through the membrane, and enter a series of ducts provided for that purpose. As the chyme, therefore, descends the alimentary tube, it is constantly losing its most fluid and nutritive portions, while other portions of it are being still farther digested and prepared for a like absorption. On reaching the cæcum, or commencement of the large intestine, it assumes a fœcal odour, and has now lost nearly the whole of its nutritive matters. Such as remain, however, are absorbed by the large intestine, whilst the useless matter becomes more and more solid, until it is expelled through the rectum. Supposing that thirty ounces of solid nutriment have been taken in the course of twenty-four hours by a healthy individual, only five of these are expelled as fœces. So that twenty-five ounces have been prepared, elaborated, and finally passed into the body to form blood, and through it into the various tissues and secretions, to supply the wants of the economy.

STAGE II.—*The Formation from the Alimentary Matters of a Nutritive Fluid, the Blood; and the Changes it undergoes in the Lungs.*

Chylification.—The nutritive matters of the food, in a state of the minutest division, pass through the cell-walls of the epithelium covering the intestinal villi, probably by endosmose, although it has been supposed that there are minute pores which permit their entrance. From the interior of these cells they pass into the extremities of ducts, called *lacteals*, in a way that has hitherto eluded all research. What, however, *has* been seen is, that, when digestion in the intestines is active, the epithelial cells of the villi are filled with the fatty molecules and granules of an emulsion, the extremities of the villi themselves appear turgid, and the lacteals within them, where they are visible, are filled with a milky fluid. The continuation of these lacteals on the peritoneal coat of the intestines is also filled with this milky fluid or chyle, which flows in a continuous stream through the numerous lymphatic glands towards the thoracic duct. The chyle, when it is first examined on leaving the intestine, presents a milky appearance, and consists of a multitude of minute molecules, or a molecular basis, when examined microscopically. After passing through the lymphatic glands, however, these molecules may be seen to be mingled with larger corpuscles, which are the lymph and chyle corpuscles previously described, and which are subsequently transformed into those of the blood.

Function of the Blood-Glands.—There are a series of glands, widely disseminated through the body, characterized by being very vascular, forming in their interior a multitude of colourless nuclei and cells, having no ducts, but richly furnished with lymphatics. To this group of organs not only belong the lymphatic glands, but the spleen the supra-renal capsules, the thymus, and thyroid glands. In infancy and early childhood the thymus and supra-renal capsules are large and active; they then decline and almost disappear in man. The others are permanently active throughout life. The lymphatic glands evidently exercise a great influence over the fluid which passes through them, the exact nature of which is unknown, but which serves to elaborate or fit it more perfectly for the function it is to undergo. The fluid derived from the intestines in the manner described passes through the mesenteric lymphatic glands, is of a milky appearance, and called *chyle;* that which goes through the other lymphatic glands is limpid, and denominated *lymph.* They also pour their contents into the thoracic duct, which in man enters the angle formed by the left jugular and axillary veins (diagram, 6); so that the whole joins the blood at that point. The thoracic duct further receives the lymphatics coming from the other blood glands, each of which contributes numerous corpuscles, in various stages of development, destined to become blood corpuscles.

Sanguification.—The blood, therefore, is formed and kept up not only by the nutritive matter derived directly from alimentary matters digested in the intestines, but by the constant secretion of fluids abounding in corpuscles derived from the blood-glands on the one hand, and lymph and matters absorbed into the circulation from the tissues of the economy on the other. Of this latter process, however, we shall speak subsequently. The formation of blood is undoubtedly connected with the reception of chyle and the function of the blood-glands. The former furnishes the proximate nutritive principles—albuminous, fatty, and mineral—reduced to a fine emulsion. In the blood-glands are produced the corpuscles according to the laws of cell growth, which, floating in the fluid, become more and more developed as they flow along the lacteals, and through the lymphatic glands towards the blood, on reaching which they are immediately transmitted through the right side of the heart to the lungs, and become blood corpuscles. Whether all the corpuscles formed in the blood-glands, and more especially in the spleen, reach the circulation through the thoracic duct, is doubtful. It is probable that the Malpighian glands of the latter organ may have some direct connection with the veins, although this has not been clearly demonstrated anatomically. The blood of the splenic vein, however, is always more rich in colourless cells than any other kind of blood; and in certain morbid conditions, where the spleen and other blood-glands are enlarged, that fluid is crowded throughout with colourless cells, constituting a morbid condition we were the first to discover and describe, denominated Leucocythemia, or white cell-blood. That the corpuscles formed in these glands, therefore, do get into the blood is certain, although the channel by which they do so has not yet been clearly demonstrated. In the lungs, most of the corpuscles in a state of health become coloured, and the blood itself undergoes important alterations.

Circulation of the Blood.—Having seen how the nutritive elements of the food are converted into blood, the method by which it is distributed or circulated throughout the organism should next be described. This circulation is carried on through the heart, the arteries, the capillaries or intermediary vessels and veins, back to the heart again. In the higher animals, there may be said to be two circulations, one connected with the body generally—the systemic or greater circulation; the other with the lungs—the pulmonary or lesser circulation. Let us suppose that it commences with the left ventricle of the heart (see diagram, 9). The blood passes from thence by the aorta through the systemic arteries into the capillaries, and back by the veins to the right auricle of the heart. From thence it goes into the right ventricle of the same organ through the pulmonary artery to the capillaries of the lung, in which it is exposed to the atmosphere, and then back through the pulmonary veins to the left auricle and left ventricle, where we saw that it commenced. In this constant round it is subject—1*st*, To various forces which serve to propel it; and 2*d*, To different changes, the result of the respiratory and nutritive processes.

1. The most important force which propels the blood is induced by the contractions of the muscular walls of the heart, an organ so constructed that, by the union of contractile cavities and valves, the fluid is constantly sent through it only in certain directions. The action of this apparatus is accompanied by certain noises, caused by the combined contraction of the muscular walls, the rushing of the fluid, and the flapping together of the valves, an exact appreciation of which is the method by which the modern physician is enabled, with wonderful accuracy, to determine the diseases or derangements of the organ.

On placing an ear over the cardiac region in a healthy person, a beating will be felt, and two sounds heard, which have been likened to the tic-tac of a watch, but to which they bear no resemblance. They may be imitated, however, very nearly, as pointed out by Dr Williams, by pronouncing in succession the syllables *lupp, dupp.* The first of these sounds, which is dull, deep, and more prolonged than the second, coincides with the shock of the apex of the heart against the thorax, and immediately precedes the radial pulse; it has its maximum intensity over the apex of the heart—below and somewhat to the inside of the nipple. The second sound, which is sharper, shorter, and more superficial, has its maximum intensity nearly on a level with the third rib, and a little above and to the right of the nipple—near the left edge of the sternum. These sounds, therefore, in addition to the terms *first* and *second*, have also been called *inferior* and *superior*, *long* and *short*, *dull* and *sharp*, *systolic* and *diastolic*—all which expressions, so far as giving a name is concerned, are synonymous. The two sounds are repeated in couples, which, if we commence with the first one, follow each other, with their intervening pauses, thus—1*st*, There is a long, dull sound coinciding with the shock of the heart; 2*d*, There is a short pause; 3*d*, The short, sharp sound; and 4*th*, A longer pause,—all which correspond with one pulsation. In figures, the duration of these sounds and pauses by some have been represented thus,—the first sound occupies a third, the short pause a sixth, the second sound a sixth, and the long pause a third. Others have divided the whole period into fours parts; of which the two first are occupied by the first sound, the third by the second sound, and the fourth by the pause. The duration as well as the loudness of the sounds, however, are very variable even in health, and are influenced by the force and rapidity of the heart's action, individual peculiarity, and form of the thorax. Their extent also differs greatly. They are generally distinctly heard at the precordial region, and diminish in proportion as we withdraw the ear from it. They are less audible anteriorly on the right side, and still less so posteriorly on the left side. On the right side posteriorly they cannot be heard. Their tone also varies in different persons; but in health they are free from a harsh or blowing character.

Great diversity of opinion has existed regarding the causes of these sounds, but we may consider that there coincides with the first sound—1*st*, The impulse, or striking of the apex against the thoracic walls; 2*d*, Contraction of the ventricles; 3*d*, Rushing of the blood through the aortic orifices; and 4*th*, Flapping together of the auriculo-ventricular valves. There coincide with the second sound—1*st*, Rushing of the blood through the auriculo-ventricular valves; and 2*d*, Flapping together of the aortic valves. Contraction of the auricles immediately precedes that of the ventricles. The result of numerous pathological observations, and of many experiments is, that in health the first sound is produced by the combined action of the auriculo-ventricular valves, of the ventricles, and of the rushing of the blood, which sound is augmented in intensity by the impulsion of the heart's apex against the thorax; whereas the second sound is caused only by the flapping together of the sigmoid valves. The tilting forward of the cardiac apex is caused by the peculiar spiral arrangement of its contractile fibres.

The inner surface of the heart is considerably more irritable than the outer, and the right auricle retains the power of contractility longer than any other part of the body, and has consequently been called *ultimum moriens.* The blood is the natural stimulus to this contractility, and hence why, the more blood is forced into it as the result of exercise and increased respiration, the more rapid its actions become. The heart, however, will continue to contract regularly when cut out of the body of an animal recently killed, and when deprived of blood; but then the stimulus is supplied by the air, or by the table on which it lies. Under any circumstances, the rhythmical action of its various parts is owing to the distribution of ganglionic nerves in its substance, constituting one of the excito-motory actions which will be subsequently described. The heart is also readily excited by various emotions of the mind, though not by volition; hence in ancient times it was considered the peculiar seat of the affections and passions, an opinion which may be still traced in numerous expressions common to the phraseology of all languages even in the present day.

The force with which the left ventricle of the heart contracts is about double that exerted by the contraction of the right, which results from the greater thickness of its walls, and the greater resistance it has to overcome. It has been calculated that the static force with which the blood is impelled in the human aorta from the ventricle is equal to that of 4 lb. 4 oz., and in that of a mare is equal to 11 lb. 9 oz. The frequency of the heart's action is modified by a variety of circumstances, which we shall allude to immediately when speaking of the pulse. The arteries are tubes composed of elastic and contractile fibrous tissues, the former being most abundant in the largest vessels, where the pressure is greatest, while the latter exists almost alone, where the impulse of the heart is scarcely felt. Their functions are,—1*st*, The conveyance and distribution of blood to several parts of the body; 2*d*, The gradual conversion of the pulsatile or wave-like movements into a uniform flow.

The blood nowhere passes through an artery so rapidly as it is forced into it by the left ventricle of the heart, on account of the resistance offered by all the tubes against which it is forced. The consequence is, that when it receives the wave of blood, both the diameter and length of the vessel is increased, and this is followed by a recoil and recovery of its previous position, owing to the elasticity of the tube. These operations constitute the pulse, which is felt when the finger slightly compresses an artery. The pulse differs after violent exercise, according to the time of the day and position of the body. Exercise raises the pulse. It is quicker in the morning than in the evening; and hence, it has been supposed, why a glass of wine is more stimulating early in the day than at night. In health, the pulse reaches its maximum about noon, and its minimum towards midnight. It is more frequent in the erect than in the sitting position, and quicker then than in the recumbent posture. The difference between standing and sitting is about 10 pulsations; between sitting and lying, 5; and between standing and lying, 15 pulsations; much, however, depends on the muscular effort employed. The natural pulse in the adult male may be stated as varying between 60 and 70 pulsations in the minute; that of the female being, on an average, about 10 beats more. In a newly-born infant, it is from 130 to 140; in old age, from 50 to 60. In diseases, the deviation from the healthy standard as to frequency is very remarkable. It has been known in profound coma to be only 17, and in cases of water in the brain in children it has been counted 200 in the minute. The volume or force of the pulse may also vary; hence the terms *strong* or *weak*, *full* or *small*, *hard* or *soft*, *rigid*, *tense*, *wiry*, *thready*, &c. As regards rhythm or time, it may be *regular*, *irregular*, *unequal*, *intermittent*, *jerking*, &c.

The capillaries, as was previously remarked, consist of delicate membranous contractile tubes, and their functions seem to be,—1*st*, To subdivide the blood, so that it may be brought within the attractive influence of the tissues; and 2*d*, To act as fine filters, permitting an exchange of matter to be constantly carried on between the blood and the textures. In the transparent webs of certain animals, the blood may be seen passing through these tubes in a state of health with a uniform flow. There is no evidence that they exercise any influence in propelling the blood by contracting their walls, but there is every reason to suppose that the constant attraction exerted by the tissues in drawing nutritive matter from the blood must exercise a considerable power in drawing the blood onwards. We observe this in plants and animals which have no hearts or contractile vessels to propel the nutritive fluid, and we see it strongly manifested where, in consequence of increased local growth, the blood increases in a part, as in the scalp during the annual growth of the stag's horns, in the breast during lactation, in the gums during dentition, and so on. In all such cases the vessels of the part are enlarged and turgid with blood, a phenomenon formerly ascribed vaguely to a "determination of blood to the part," but now known to result from the increased attractive force exercised by the tissues on the blood in places which are the seat of excessive local growth. The same theory serves to explain, as we shall subsequently see, the phenomenon of the morbid process known as inflammation.

The veins arise from the capillaries, and are similar in structure to the arteries, with the exception that the elastic tissue is not so thick. It has been supposed that the forces propelling the blood through the arteries and capillaries are sufficient to cause its return to the heart through the veins, but this is assisted by internal valves and by the respiratory movements of the chest. The former are numerous, and so arranged that the blood can never return towards the capillaries. Every motion of the body and contraction of the muscles through which veins pass must—by compressing them, and thereby squeezing the blood towards the heart—assist its transit. Expiration favours the flow of blood in the arteries, and inspiration favours it in the veins, but does not operate in vessels distant from the thorax, and even in them to no great extent.

It is very difficult to determine the rapidity of the blood in different parts of the circulation. The most satisfactory results have been arrived at from watching the period occupied by poisons in passing from one part of the body to another, as in the experiments of Blake. From them it would appear that a portion of blood can traverse the entire circulation in the horse in half a minute.

The circulation presents peculiarities—1*st*, In different parts of the body; 2*d*, In the fœtus; 3*d*, In various animals, to particularize which here would lead us too far. One of the most important of these peculiarities occurs in the cranium, which being an unyielding osseous case, its contents are pressed upon by the atmosphere from below, like an inverted jar in a pneumatic trough. The result is, that so long as the cranial walls are uninjured, it must always hold the same amount of fluid. Hence the notion, that by general or local bleeding you can draw blood from the brain, is erroneous, although, by weakening the action of the heart, it is of course possible to diminish the pressure it exercises on the cerebral vessels.

2. The changes which the circulating fluid undergoes during its transit through the body are, the conversion of arterial into venous blood in the systemic capillaries, and its re-conversion into arterial blood in the pulmonary capillaries. This leads us to discuss in the next place the function of—

Respiration.—This is carried on by means of lungs, the structure of which organs is so arranged as to expose a large surface, covered with capillary blood-vessels, to the action of the atmosphere. The dilation of the chest during ordinary inspiration is principally owing to the contraction and descent of the diaphragm muscle. But when a deep breath is taken, the cavity of the chest is further dilated by the intercostal, scaleni, serrati, and other muscles. Expiration ordinarily is owing to the elasticity of the lungs and walls of the chest, aided by the contractions of the abdominal muscles. During forced expiration the *longissimus Dorsi*, *Sacro lumbales*, and other muscles, cooperate.

The number of respirations which occur in the minute during health are from fourteen to eighteen, but in disease they have been known to be so low as seven, and so high as a hundred. The amount of air inspired also varies; in health ranging from 20 to 25 cubic inches (Coathupe). A man's average breathing capacity is best tested by a forcible expiration, which yields, according to Hutchinson, 225 cubic inches, as measured by the spirometer.

The great change which the atmospheric air undergoes in going into and coming out of the lungs is the removal of a portion of the oxygen, and the substitution of a quantity of carbonic acid gas. For a long time it was supposed that the loss of the one was exactly equal to the production of the other, but it is now known that the volume of oxygen which is absorbed is far greater than that of the carbonic acid given off; and hence we must conclude that the former gas serves not only for the oxidation of carbon, but also of hydrogen in the animal organism. If the air be already charged in some degree with carbonic acid gas, the quantity exhaled is much less, a circumstance which strongly points out the necessity of ventilation. It is not sufficient for health that a room should contain the quantity of air requisite for the respiration of its inhabitants during a given time, since long before its exhaustion it will contain a quantity of carbonic acid sufficient to interfere with the necessary excretion from the blood. Hence the headache and other symptoms often experienced in breathing confined air. The manner in which oxygen is absorbed and carbonic acid given off, seems owing to the physical law described by Professor Graham with respect to diffusion of gases; and the quantity of the former which enters will be much greater than that of the latter, which passes out in the proportion of 1174 to 1000. The one-sixth of oxygen which thus enters the body, and is not converted into carbonic acid, is supposed to combine with hydrogen, furnished by the food and by the disintegration of the tissues, to produce water. Part of the water so formed is again exhaled in the form of vapour from the lungs, whilst another part is used in oxidizing the sulphur and phosphorus taken in with the food, and excreted chiefly in the condition of sulphuric and phosphoric acids. The absolute quantity of solid carbon given off by the lungs is about 160 grains per hour, or 8 oz. troy in the twenty-four hours. The amount of watery vapour given off varies from 6 to 27 oz., according to the nature of the diet, amount of exercise, temperature, humidity of the atmosphere, &c., &c. As regards the effects of respiration on the blood, the most striking is the change of colour of the claret-like venous into the bright scarlet of arterial blood. The temperature of arterial blood is one or two degrees higher than venous blood. (Davy.) The specific gravity and number of corpuscles also are said to be somewhat greater, and it contains a larger amount of oxygen and less carbonic acid.

Numerous chemical theories have been advanced to explain the manner in which oxygen is removed from the inspired air, and a quantity of carbonic acid gas added to expired air. But whether the oxygen, after forming an acid, unites with the alkalies,—whether it attaches itself to the corpuscles or to the fibrin, or unites with phosphorus and fatty matter, are points not yet finally determined.

If respiration be embarrassed or difficult, it constitutes *dyspnœa* ; if arrested, from exclusion of atmospheric air, *asphyxia* is produced. As a general rule, if the air be cut off from the lungs of a warm-blooded animal by strangulation or immersion in water, all external muscular movements will cease in a period varying from three to five minutes, and the circulation comes to a stop in two minutes. Some individuals, by force of habit, seem to have acquired the power of retaining their consciousness for a considerable time under water, as in the divers of Ceylon, some of whom have been known to remain immersed, and actively picking up oysters, from three to five minutes. This period, under ordinary circumstances, is sufficient to induce death, for few persons recover who have been under water four minutes. Exceptional instances indeed are on record where persons have revived after a submersion of half an hour. It is supposed, however, that in these a state of syncope was occasioned at the moment of immersion, from fear, mental emotion, or concussion of the brain, so that in them respiration did not exist in its full activity. To restore asphyxiated persons no time should be lost. The individual should be immediately placed on the abdomen, to allow of the tongue falling forwards, and any fluid in the mouth to escape. One of the arms should be put below the forehead, to prevent the possibility of the nose and mouth being compressed by the ground. The body should then be alternately rolled on the side, and again placed on the abdomen, so as to imitate the compression and expansion of the chest in respiration. The extremities should be assiduously rubbed, especially pressing upwards, and warmth applied.

STAGE III.—*Passage of Fluid from the Blood to be transformed into the Tissues.*

We have now seen how nutritive matter enters the body, and the changes it undergoes to be transformed into blood. We have also seen how the blood is carried to all parts of the organism. We have next to trace how that organism is built up and maintained by substances derived from that blood.

We have previously shown that the tissues have a vital property of attraction and selection, whereby the necessary materials are drawn through the delicate membranous walls of the capillaries, and transformed chemically and structurally into the textures. We are forced to adopt this theory, for it can easily be shown that all the tissues depend on one fluid, the blood, for their nourishment; whilst it is also clear that this same fluid in different tissues and organs gives rise to different chemical and structural results. In this manner, an animal is maintained for a series of years with the same physical characters, the different proportions between the supply and loss causing the rapid growth of the young, the stationary period of adult life, and the decline of age. Of the ultimate causes of the different variations in growth we know nothing. All that science can accomplish is to obtain a knowledge of the conditions on which it depends. Some of these we have spoken of when describing the cell theory, but there are four others to which we shall allude in this place.

1. *A healthy quality of the blood* is necessary for a

healthy formation of texture, and this implies that all the processes of nutrition should be properly performed, including digestion, assimilation, respiration, secretion, excretion, and so on. Any one of these being disturbed, growth of the body, in whole or in part, may be faulty from want of appropriate material. The blood, however, enjoys to a certain extent the power of spontaneously correcting its own deteriorations, and if these be not excessive or too long continued, it rapidly separates, or gets rid of them by means of some apparatus, and its normal characters are restored. We are continually meeting with these occurrences during our observation of disease; and in this way we account for and see the use of occasional diaphoresis, diarrhœa, epistaxis, loaded urine, and so on. It is also possible that the excretion of one substance is more or less connected with the formation of another, as in the instances of what Mr Paget calls *complemental* nutrition, of which the growth of the beard in man, and of the mammæ in females at the period of puberty, are illustrations.

2. *A proper quantity of blood in a part* is also essential for growth, as is proved by the effects of those occurrences which, by destroying or injuring the principal vessel leading to it, causes its wasting or death. It is also observable that whenever parts are actively growing, they attract more blood to them than usual, showing that there is an intimate relation between activity of formation and the quantity of blood in the textures.

3. *A certain influence of the nervous system* is so blended and mingled with nutrition of parts in the higher animals that the improvement of the one materially interferes with the advancement of the other. Thus there is scarcely an organ in the body the functions of which may not be

more or less deranged by various conditions of the mind. Hope and confidence are highly favourable to the resolution of numerous diseases; while fear and a foreboding of evil seldom fail to aggravate the most simple maladies, and in dangerous ones often render them fatal. Destruction of a nerve leading to a part not only may cause wasting of the tissue, but often ulceration and destruction of it. The same occurs when disease attacks the spinal cord.

4. *A healthy state of the part to be nourished* is as necessary for growth as the other conditions mentioned. If the property of attracting and selecting materials from the blood be inherent in the textures themselves, as we have seen is probable, it follows that, if these textures be seriously altered or destroyed, the property will also be altered or destroyed. Now, this is what really takes place; and hence why so many diseases of texture, once occasioned, are kept up in spite of all the interference of art. Such is the reason, also, that blows and other injuries, by exciting or diminishing the vital properties of the textures, give rise to what are called inflammations, tumours, and other forms of so-called morbid growths.

Such are the conditions which serve to regulate growth in the animal economy. The process may be in excess or diminution, constituting what is called *hypertrophy* and *atrophy*. There is one modification of growth, however, which we must refer to especially, and which has long been known under the name of *secretion*.

Secretion.—This process was for a long time considered as one opposed to growth; that is, as a function having for its object to separate matters from, while growth was directed to storing up or adding them to, the organism. We now know that secretion is simply a form of growth, and is carried on under the influence of the same laws which regulate the development, maturation, and decline of nucleated cells in general, and of the conditions just referred to in particular. Under the head of "Cell Tissues" we have alluded to the peculiar properties of secreting cells. They are generally formed on one side of a basement membrane, while on the other side blood-vessels are distributed, from which their contents are derived. The variations in glands simply result from the convolutions and greater or less complexity of these universal gland elements. No relation apparently exists between the structure of the glandular apparatus, or the nerves supplying it, and the secretion it pours forth. Thus the pancreas, the lacrymal and mammary glands, are very much alike in their anatomical elements, although the pancreatic and lacrymal fluids and milk are widely different. This fact is sufficient to convince us that a property of a peculiar kind, essentially vital, must reside in the cells themselves, which occasions these results.

STAGE IV.—*Disappearance of the Transformed Tissues, and their Re-absorption into the Blood.*

While, on the one hand, matters are always passing from the blood to build up the tissues, on the other, matters are continually passing into the blood from those tissues which have fulfilled their appointed functions. The new material takes exactly the place and form of the old ; so that the general configuration of the body is preserved, while continually and imperceptibly undergoing a change. Although in adult animals we cannot see the tissues forming, in the embryo we can, and are consequently enabled to infer the steps of the process. But we cannot see the healthy tissues disintegrating and absorbing, even in the embryo ; and this source of information is therefore cut off from us. Almost all that we know of this process, from actual observation, is derived from the study of morbid anatomy. From this we learn that new formations, such as pus and cancer cells, break down and are reduced to a fluid state in the inverse order to that in which they were developed. Thus a fluid exudation is poured out from the vessels. It coagulates in the form of molecules and granules. These unite to form nuclei, around which cell-walls are produced. If this be their ultimate point of development, they are again reduced to the fluid state, first by the solution of the cell-wall, and subsequently by that of the nucleus. The whole now again presents a molecular and granular aspect, whilst the more fluid portions again pass through the walls of the blood-vessels, and enter the circulation. We do not see this process in health, but doubtless particle after particle of solid matter is reduced to fluid, and disappears, in order to give place to new particles, which for a time become solid, assume form, fulfil their function and allotted period of life, and then dissolve, are absorbed and excreted as their predecessors were before them.

Function of the Blood.—The blood, therefore, is a wonderfully complex fluid, partly made up of organic materials derived from the alimentary canal and blood-glands (*primary digestion*), partly derived from organic materials derived from the tissues and gaseous fluids received from the atmosphere through the lungs (*secondary digestion*). The constituents thus obtained from such various sources are modelled and changed during the circulation, so that they may readily pass off by other channels, and so escape from the economy. The stream of blood carries them to the various excretory organs, where they are separated; and thus the vast importance of a continued circulation of fluid is made manifest, not only in carrying materials of growth to build up the frame, but in removing the effete or worn-out particles which have fulfilled their office. In this manner, the circulation of the blood may be compared to a river flowing through a populous city, which not only supplies the wants of its inhabitants, but conveys from them all the impurities which, through numerous channels, find their way into its stream. The general properties of this fluid now demand attention.

The blood corpuscles of which we have previously spoken float in a straw-coloured transparent fluid, the *liquor sanguinis*, which, when it ceases to circulate in the vessels, has the property of coagulating. This may be seen under the microscope to take place, in consequence of the deposition of the fibrin held in solution, in the form of molecular fibres, whereby a fibrous mesh-work is produced, entangling the corpuscles. The clot of the blood, therefore, is composed of the fibrin and corpuscles, while the serum is set free. When the blood coagulates slowly, or is unusually viscous from an increase of its fibrin, the corpuscles sink to the bottom, leaving a colourless layer on the surface of the clot, which was formerly supposed erroneously to be a distinctive sign of inflammation. In addition to fibrin, the *liquor sanguinis* holds in solution albumen, fat, and salts, and all those substances which are necessary, directly or indirectly, for the formation of the tissues and secretions. It may be regarded as the most elaborated portion of the blood, inasmuch as the corpuscles are dissolved in it; and, as previously stated, it receives the results both of the primary and secondary digestions. So prepared, it is the essential material or nourishing fluid, which, attracted through the capillaries by the tissues, is the foundation for all the formative processes of the economy.

Chemical Composition of the Blood.—The chemical constitution of the blood has been investigated by numerous distinguished chemists. We give the results arrived at, from a large number of data, by Becquerel and Rodier:—

Table, showing the Maxima, Minima, and Average Numbers of the Different Constituents in 1000 *parts of the Blood of Man*:—

	Mean.	Maxima.	Minima.
Density of defibrinated blood	1060·2	1062·0	1058·0
Density of serum	1028·0	1030·0	1027·0
Water	779·0	800·0	760·0
Blood corpuscles	141·1	152·0	131·0
Albumen	69·4	73·0	62·0
Fibrin	2·2	3·5	1·5
Extractive matters and free salts	6·8	8·0	5·0
Fatty matters	1·600	3·255	1·000
Serolin............................	·020	·080	impond.
Phosphorized fat.................	·488	1·000	·270
Cholesterin	·088	·175	·030
Saponified fat	1·004	2·000	·700

From 1000 parts of blood, after calcination, they obtained—

Chloride of sodium..............	3·1	4·2	2·3
Other soluble salts	2·5	3·2	2·0
Phosphates	·334	·7	·225
Iron	·565	·633	·508

We may say that the chemical composition of the blood in a general way is as follows:—1*st*, The great bulk of the blood is made up of water, varying in a healthy state from 760 to 800 parts in 1000; 2*d*, The fibrin is small in quantity, varying from ½ to 3 parts; 3*d*, The amount of albumen ranges between 60 and 70 parts; 4*th*, The blood corpuscles vary from 130 to 150 parts; 5*th*, The extractive matters and fat range from 1 to 4 parts; and 6*th*, The saline matters range from 5 to 10 parts. These are not the exact proportions, but approximative results, which are more easily retained by the mind. The mean amount of this fluid in the human adult male is 34½ lb.; in the female, 26 lb. (Valentin.) These various results differ in diseased conditions of the body, concerning which the following conclusions were formed by Becquerel and Rodier:—1*st*, That the simple fact of the development of a disease almost always modifies in a notable manner the composition of that fluid. 2*d*, That venesection exercises a remarkable influence on the composition of the blood; the more marked, the oftener it is repeated. Under these circumstances, the blood is impoverished and rendered more watery; the albumen is slightly diminished; the fibrin, extractive matters, and free salts are not influenced, but there is a decided diminution of the corpuscles. 3*d*, That in a plethoric condition of the system there is no relative increase in the number of the corpuscles, or in fact in any other change in the composition of the blood; it is simply the mass of the blood that is increased. 4*th*, That anæmia is characterized by a diminution in the amount of the corpuscles. 5*th*, That inflammation induces an increase of the fibrin and of the cholesterin; the former varying from 4 to 10, and the latter being almost doubled. The albumen is diminished. 6*th*, That the amount of fibrin is diminished, and possibly its physical conditions altered, under two conditions. The first embraces fevers, exanthematous diseases, and intoxication; the second, starvation and *purpura hæmorrhagica*. 7*th*, That when any of the secretions are checked, their essential principles are contained in the blood in excess. For instance, when secretion of the urine is suppressed, urea is found in the blood; when the bile is not excreted, it abounds in the blood, &c. And 8*th*, That there are three diseases in which the albumen of the blood is notably diminished,—viz., in Bright's disease, in certain affections of the heart accompanied by dropsy, and in severe cases of puerperal fever.

Animal Heat.—Many of the processes we have described are accompanied by an exchange of chemical elements, which, in the act of forming new combinations, evolve heat. Thus the union of oxygen with the blood in the lungs, and the formation of carbonic acid gas in the capillaries make up together the amount of animal heat found in the body. The average temperature, as estimated by placing a thermometer in those internal parts which are most easily accessible, is from 98° to 100° Fahrenheit. In children it is about 2° higher. In febrile diseases it has been observed to rise to the height of 108°·5 in children, and to 107° in adults. In Asiatic cholera it may sink to 77°, or even lower, and the breath itself feels cool to the naked hand. The natural temperature of the body, though slightly affected by temperature, food, and exercise, is on the whole pretty stationary ; a circumstance which for the most part is owing to the power of evaporation possessed by the skin. Hence the danger of suddenly checking perspiration, in exposing the surface to cold. The temperature of the various tribes of animals differs considerably, birds having a higher, and reptiles and fishes a much lower temperature than mammals, according to the medium they live in. They cannot, however, endure severe changes in external heat and cold. Man alone, by his power over food and the supply of artificial clothing and exercise, is enabled to bear without injury extremes of atmospheric temperature that no other animal could endure.

We have seen that more oxygen is taken in by the lungs than escapes from them in the form of carbonic acid gas. This excess, by uniting in the tissues with the carbon and hydrogen received into the system as food, produces heat; and the carbon in its conversion into carbonic acid, and the hydrogen in its change into water, gives off exactly the same amount of heat as if these processes had been carried on out of the body. Hence the quantity of heat generated bears a direct relation to the activity of respiration and the supply of food. Thus the respiratory process is most active in birds, and they possess the highest animal temperature; and in reptiles, in whom respiration is slow, the heat evolved is much less. Even in man all the circumstances which induce rapid breathing, such as exercise, occasion increased heat. As regards the influence of food, we observe that in northern climes, where the oxygen in the air is more abundant, the quantity of food taken is greater than among the inhabitants of tropical countries. The nature of the food, also, in the one, abounding in fatty and oily substances rich in carbon and hydrogen, is better adapted to combine rapidly with the excess of oxygen than the vegetable and starchy compounds used in others. The effects of alcohol, a highly carbonaceous substance, in keeping up animal heat, is in like manner thus explained; a substance which, rapidly entering the blood, combines with the excess of oxygen, and thus supports the temperature of the body when exhaustion from want of food, or from exercise too long continued, has been occasioned. Thus, in the words of Liebig, to whom we are indebted for establishing this theory of animal heat, "The animal body acts as a furnace, which we supply with fuel. It signifies nothing what intermediate forms food may assume, or what changes it may undergo in the body; the last change is uniformly the conversion of its carbon into carbonic acid, and of its hydrogen into water; the unassimilated nitrogen of the food, along with the unburned or unoxidized carbon, is expelled in the urine or in the solid excrements. In order to keep up in the furnace a constant temperature, we must vary the supply of fuel according to the external temperature, that is, according to the supply of oxygen. Hence, in the animal organism two processes of oxidation are going on; one in the lungs, the other in the capillaries. By means of the former, in spite of the degree of cooling, and of the increased evaporation which takes place there, the constant temperature of the lungs is kept up, while the heat of the rest of the body is supplied by the latter."

STAGE V.—*Discharge of Effete Matters from the Body in Various Forms and by Different Channels.*

We have already seen that the textures of the body, while they are continually assimilating new particles of matter from the blood, are constantly giving up to that fluid the particles which have lived and are worn out. These in a fluid form, but more or less chemically changed, constitute the fibrin, and a portion of the fat, extractive matters, and salts which circulate in that fluid. They are the results of the disintegration of the tissues,—that is, of the secondary digestion of organic matter which takes place in the body,—and being useless, are now separated from the economy in the following ways, as—

1. *Excretion from the Lungs.*—A large amount of watery vapour and of carbonic acid are, as we have seen, continually passing off from the lungs. The water thus exhaled daily varies from 6 to 27 oz., and the carbon, in the form of carbonic acid, separated in the same space of time, amounts to 8 oz. troy. In addition, then, to considering the lungs as organs which supply oxygen to the blood, and as supporters of animal heat, they must be regarded as an apparatus of excretion, whereby oxygen, hydrogen, and car-

bon are continually separated from the body in a given form. Under the heads of "Respiration" and "Animal Heat" we have sufficiently dwelt on these points.

2. *Excretion from the Liver.*—Bile, as we have previously seen, is a secretion, but as it is one of those secretions which are produced in order to be excreted, and as the principal function of the liver is the separation from the blood of matters which, if retained, would be injurious to it, we must speak of it in this place.

The blood which supplies the liver is, like that which goes to the lungs, venous, and the portal vein which carries it there originates for the most part from the intestines (diagram, 12, p. 48). Hence it differs from other blood in more frequently containing principles derived from the primary digestion, more especially fat, dextrine, and sugar; whilst it does not possess so much fibrin, a substance principally formed from the secondary digestion; so that the clot it forms is deficient in firmness. The food, in traversing the alimentary canal, not only parts with substances which enter the systemic circulation to form blood, but also with portions of its material which enter the blood-vessels, and are at once directed through the portal vein to the liver, in order to form bile. We can easily understand, therefore, how rich eating and little exercise favour the production of those symptoms which are denominated *bilious.*

When the blood arrives by the portal vein at the liver, it breaks up into a multitude of minute capillaries, which, with a mass of secreting cells filling up the interspaces between them, are arranged in small masses or lobules. The vital property of the cells is to attract and select from the blood materials which they fashion into bile in their interior, and this is subsequently discharged into ducts, and accumulated in a gall-bladder until it joins the food in the duodenum, as previously described. The bile thus formed is a viscous yellow or greenish fluid, and of strong bitter taste. The quantity of it formed daily has been estimated at 17 or 24 oz., but this varies under a great variety of circumstances. It is composed of water holding salts in solution, with about 80 in 1000 parts of mucus, colouring matter, and fat. The salts are those of soda, potash, and ammonia, in combination with acids, one of which contains sulphur as a constituent. The colouring matter is called *biliphin*, and the fatty matter is composed principally of cholesterin, mingled with a small proportion of fatty acids.

Bile is excreted in two ways. A portion of it, including the colouring matter, passes through the whole alimentary canal. The greater portion, however, is absorbed into the blood, and is ultimately carried off by the respiratory process in the form of carbonic acid. The amount of the excretion in these two ways varies greatly, one being to a certain extent increased if the other be diminished. It is absolutely necessary for the bile to be conducted out of the system, and if, through any obstruction in the duct, it be prevented from being discharged, the bile enters the blood, producing jaundice, and acts as a poison. Although, therefore, the bile is useful as a secretion in operating on the chyme, there can be no doubt that its principal function is that of purifying the blood of hydrogen and carbon, and acting as an excretion.

The liver also secretes a large quantity of free fat, which, accumulating in the cells of the organ, often causes its enlargement, or so-called *fatty liver*. It has further been shown by Bernard constantly to secrete a substance which, when separated, presents all the physical and chemical properties of hydrated starch. The moment this comes in contact with the blood of the hepatic vein, it is converted into sugar, which in its turn is decomposed by the oxygen of the air in the lungs, and there disappears. If the pulmonary action be insufficient to accomplish this, the sugar becomes in excess in the blood generally, and is excreted by the kidneys, forming the disease known as *diabetes.* Hence also why a section of the pneumo-gastric nerves, injuring the fourth ventricle of the brain, and occasionally blows on the head, may occasion diabetes. The liver, whether giving off bile, fat, or starch, is thus evidently a great excretor of hydro-carbon, which is converted into water and carbonic acid, and given off by the lungs.

That the lungs and liver are to a certain extent associated for the purpose of a common function, is further shown by the circumstance, that in those cases where the lungs imperfectly separate carbonic acid gas, the action of the liver is particularly apt to be disturbed. Thus, if more non-nitrogenized food be taken than can be got rid of by the lungs in the form of carbonic acid, the liver pours a greater quantity of bile into the duodenum, causing those symptoms known as *bilious.* This is what happens frequently to Europeans in tropical climates. The rarity of the atmosphere, and the little exercise which is taken, throws increased work upon the liver. The appetite is stimulated by drugs and spices, which increase the disturbance, rendering a return to Europe necessary. All such persons, therefore, should carefully adapt a certain diet to the amount of exercise they take and the vigour of the respiration, avoiding carbonaceous, especially oily food, and alcoholic drinks, and living according to the simple habits of the natives.

Excretion from the Kidneys.—The two kidneys contain in their cortical substance globular convolutions of capillary vessels, which hang in the blind extremities of the tubular glands. This arrangement permits the ready passage of a large amount of water from the blood, which, as it flows out through the duct, receives the secretion formed by the cells which line them. The whole accumulates in the urinary bladder in the form of urine, and is expelled from time to time voluntarily (diagram, P and R, p. 48). The daily amount of urine discharged in a healthy person is about 35 fluid ounces. It is of a wine-yellow colour, and slightly acid in its re-action on vegetable colours. Its composition, according to Becquerel, is as follows:—

Water			967·
Urea			14·230
Uric acid			·468
Colouring matter			inseparable... 10·167
Mucus and animal extractive matter			
Salts...	Sulphates...	Soda	8·135
		Potash	
	Bi-phosphates...	Lime	
		Soda	
		Magnesia	
		Ammonia	
	Chlorides...	Sodium	
		Potassium	
	Hippurate of soda		
	Fluate of soda		
Silica			traces
			1000·000

The proportion of these constituents varies considerably, even in health, according to the amount and quality of the food and drink, the occupation, period of life, sex, and other circumstances. In disease the variations are still greater. The quantity, as a whole, may be increased or diminished, and the saline constituents may be so augmented as to be deposited on cooling, causing the formation of various salts. The urine may also be loaded with foreign substances, as blood, albumen, pus, sugar, &c. Hence why a careful examination of this fluid is so important to the physician, as indicating a variety of morbid conditions, not only of the urinary organs themselves, but of the constitution generally.

The kidneys, therefore, separate—1*st*, A large quantity of the water which enters the body as drink; 2*d*, Certain materials derived from the primary digestion; and 3*d*, Matters the result of the secondary digestion, or disintegration of the tissues. The principal object of the kidney is to separate two substances rich in nitrogen; so that, while the liver may be considered as an organ excreting hydrocarbon, the kidneys must be regarded as organs which separate nitrogenous substances. The forms these assume are two, viz., urea and uric acid. Of the former, 270 grains, or more than half an ounce, are excreted by a healthy man daily, and of the latter, somewhat more than 8 grains. According to Liebig, when the vital force in the albuminous tissues is no longer able to resist the chemical action of the oxygen which is conveyed to them in the arterial blood, it combines with their elements, and forms products, among which uric acid is the most important. But if sufficient oxygen and water be conveyed into the arterial blood, the greater part of the uric acid, or more insoluble salts, is converted into urea and carbonic acid; so that the effete nitrogenized elements of the tissues reach the emunctories in a soluble form, a condition necessary for their ready secretion. Hence the more oxygen enters a tissue during its disintegration, the more complete will be the conversion of the insoluble uric acid into the soluble urea, and the more easy its elimination from the body.

In this manner is explained how the urine of the boa-constrictor is semi-solid, consisting almost entirely of bi-urate of ammonia, as the animal eats an enormous meal of nitrogenous food; but being a cold-blooded, slowly-respiring animal, it takes in too little oxygen to convert the uric acid into urea. On the other hand, the lion and the tiger, equally carnivorous with the serpent, are rapidly-respiring, warm-blooded animals; and although, from their violent muscular exertions, rapid and great destruction must occur, scarcely a trace of uric acid is found in their urine, as it is all converted into urea at the moment of its formation, in consequence of the abundant supply of oxygen. The non-nitrogenized elements of our food, however, considerably interfere with the conversion of uric acid into urea, because they also combine with oxygen. Hence, according to Liebig, man, being an omnivorous animal, partakes of a sufficient amount of food rich in carbon to prevent the complete conversion of insoluble uric acid into soluble urea; consequently, the former substance appears in the urine, its proportion to urea being as 1 to 32.

In addition to urea and uric acid, which are the excretory products of the nitrogenous compounds, the kidney is continually separating from the blood a large quantity of earthy salts. These are excreted daily, to the amount of 138 grains, and they consist of combinations of chlorine, sulphuric, and phosphoric acids, with soda, lime, magnesia, and potass. Of these, the phosphatic salts are by far the most important. It has been calculated that about 6½ grains of phosphoric acid are thrown off by the kidneys in twenty-four hours, which are united to the four bases,—soda, ammonia, lime, and magnesia,—forming two double and one simple salt,—viz., the ammoniaco-phosphate of soda; the ammoniaco-magnesian, or triple phosphate; and the phosphate of lime.

Both the organic and mineral products may undergo excess or diminution, resulting from derangements in the primary or secondary digestive processes. Excess of uric acid in the blood may arise in two ways, constituting a tendency to gout or rheumatism,—the first from indulgence in eating, the second from hard labour and wasting of the tissues. The mineral salts may also form in abundance in consequence of eating substances which contain them; or from disintegration of the textures, the result of severe study, or, as occurs in old age, from their natural decay.

Excretion from the Skin.—The skin not only serves as a very efficient protective covering to the body, but is a most important organ, constantly excreting watery and fatty matters. The epidermis, hair, and various appendages which grow from the surface, may, in addition to the special purposes they are fitted for, also be regarded as excretory.

The water separated from the blood by tubular glands—the so-called sudoriparous or sweat glands—is for the most part carried off from the surface in the form of vapour as fast as it is separated. When, from increased exertion or other cause, the perspiration is augmented in quantity, or when, from a greater degree of moisture in the atmosphere, it is not readily evaporated, it becomes visible in the form of minute drops, which distil from the surface. The fluid consists principally of water, holding in solution a small quantity of the salts of soda, potash, and lime, with a trace of oxide of iron. The amount given off daily varies greatly—the maximum, according to Seguin, being 5 lb., and the minimum, 1 lb. 11 oz. 4 dr. The average quantity, according to Valentin, is 2½ lb. There is an intimate relation between the functions of the skin and those of the lungs and kidneys,—the one being more active when the other is depressed. Animals, on being covered with an impermeable varnish die, with all the symptoms of asphyxia, while the temperature of the body rapidly sinks 36 degrees. Again, skin diseases, and especially febrile eruptions, materially affect the kidney, and thereby give rise to secondary dropsies.

An oily fluid is constantly poured out on the skin from another series of follicular or sebaceous glands, preventing it from being dried and cracked by the action of the sun and air. Hence it is more abundant in the races which inhabit warm climates. In these, and many of the lower animals, the sebaceous matter possesses a distinctive odour, whereby they can readily be traced by quick-scented dogs. Generally speaking, the oily matter excreted from the skin is conveyed directly to the surface of the hairs or other epidermic appendages in those parts of the integument which are supplied by them.

The hair and nails grow from the base of a follicle or gland, and are developed from the cells formed in the base of such follicle so as to form a fibrous structure. A hair, if allowed to grow, tapers towards a point, and then splits up like a painter's brush, becomes brittle, and breaks off. There can be no doubt that the oily or sebaceous matter which nature has provided to lubricate such structures keeps them soft, and prevents their breaking off too suddenly. The colour of the hair depends upon the presence of pigment secreted within the cells of the follicle. Well-authenticated instances of hair turning white in a short period, from excessive grief or anxiety, are known. According to Vauquelin, this is owing to the secretion of an acid fluid, which percolates the hair, and chemically destroys the colouring matter. In the various classes of animals the epidermic appendages serve the purposes of warmth, of defence, or as aids to the sense of touch; and the modifications they undergo,—as seen in horn, the quills of the porcupine, the feathers of birds, the scales of fishes, the wing-cases and spines of insects, &c.,—embrace a singular variety of form, constituted of the same structure.

The colour of the skin was formerly supposed to exist in a distinct membrane called the *rete mucosum*, situated between the epidermis and chorion. It is now known to depend on the deposition of pigment in the lower cells of the epidermis, or those nearest the blood-vessels, and to be influenced by the general laws which regulate the formation of pigment in the animal and vegetable worlds.

Excretion from the Intestines.—We have seen that the solid nutritive matter received as food daily ought to amount to 30 oz.; of these, 25 oz. are absorbed, and only 5 oz. rejected daily from the intestines. These consist of certain parts of the food which have escaped the digestive process, and of various secretions which have been poured into the alimentary canal during its passage. Among the latter are numerous crystals of triple phosphate, showing that earthy matters are excreted in large quantities by this channel. In the large intestine, and especially in the cæcum, a further chemical change is effected. In the latter situation the peculiar fœcal odour is first produced, owing, it is supposed, to the secretion of an acid liquid there, causing another kind of digestion.

Such is a general sketch of the function of nutrition, from which we observe, from an extended point of view, that it is a continuous round, which in the natural world may be said to commence with the reception and terminate with the preparation of aliment, vegetable or animal. This is observable not only in the "chemical balance of organic nature," so beautifully described by Dumas, but in the incessant chemical compositions and decompositions, as well as structural formations and disintegrations, which are peculiar to all vital entities. If so, it must be apparent that our knowledge of the animal economy, and of the diseases to which it is liable, can only be elucidated by investigating the nature of such chemical and structural changes, together with the necessary relations that each one bears to the others, and that it is on such kind of knowledge alone that medicine as a scientific art can ever repose in security.

We can, for instance, now readily understand how derangement in one stage of the nutritive process more or less affects the others. Thus, if alimentary matters are not furnished in sufficient quantity, and of a proper quality, the blood is rendered abnormal, and it necessarily follows that the matters it gives off will be abnormal also, and its subsequent transformations more or less modified. Again, if secretion be checked, the blood is not drained of its effete matter; and if excretion be prevented, the secretions themselves may enter the blood, and act upon it as a poison.

A diseased or morbid state of the blood, therefore, may arise from either of the stages of nutrition we have described being rendered irregular or otherwise abnormal. In whatever part of the circle interruption takes place, it will, if long continued, affect the whole. Thus, a bad assimilation of food produces through the blood bad secretions and excretions, whilst an accidental arrest of one of the latter reacts through the blood on the assimilating powers. The forms of disease thus arising may be endless; but as regards nutrition, they may all be traced to the following causes:—

1. An improper quantity or quality of the food.
2. Circumstances preventing assimilation or impeding respiration.
3. Altered quantity or quality of nutritive matters passing out of the blood.
4. The accumulation of effete matters in the blood.
5. Obstacles to the excretion of these from the body.

Examples in which each of these causes, separately or combined, have occasioned disease, are of frequent occurrence. It is true that all general diseases are accompanied by certain changes in the blood, but these changes are to be removed, not by operating on that fluid directly, but by obviating or removing those circumstances which have deranged the stage of nutrition primarily affected. For instance, a very intense form of disease may be produced in infants from improper lactation. The remedy is obvious, and we procure a healthy nurse. Ischuria is followed by coma, from the accumulation of urea. We give diuretics to increase the flow of urine, and the symptoms subside. In the one case we furnish the elementary principles necessary for nutrition ; in the other, we remove the residue of the process. In both cases the blood is diseased, but its restoration to health is produced by acting on a knowledge of the causes which led to its derangement.

In the same manner we might illustrate the indications for correct practice in the other classes of causes tending to derange the blood, which we have enumerated. Thus, although there be a proper quantity or quality of the food, there may be circumstances which impede its assimilation ; for instance, a too great acidity or irritability of the stomach, the use of alcoholic drinks, inflammation or cancer of the organ. It is the discovery and removal of these that constitute the chief indications of the scientific practitioner. Again, the capillary vessels become over-distended with blood, and the exudation of *liquor sanguinis* to an unusual amount takes place, constituting inflammation. How is this to be treated ? In the early stage, topical bleeding, if directly applied to the part, may diminish the congestion, and the application of cold will check the amount of exudation. But the exudation having once coagulated outside the vessels, acts as a foreign body, and the treatment must then be directed to furthering the transformations which take place in it, and facilitating the absorption and excretion of effete matter. This is accomplished by the local application of heat and moisture, the internal use of neutral salts to dissolve the increase of fibrin in the blood, and the employment of diuretics and purgatives to assist its excretion by the kidneys or intestines.

The general principle we are anxious to establish from this general sketch of the nutritive functions is—that diseases of nutrition and of the blood are only to be combated by an endeavour to restore the deranged processes to their healthy state, in the order in which they were impaired; that for this purpose, a knowledge of the process of nutrition is a preliminary step to the proper treatment of these affections; that the theory of acting directly on the blood is incorrect; and that an expectant system is as bad as a purely empirical one.

FUNCTION OF INNERVATION.

The function of innervation, like that of nutrition, consists in the performance of various actions, widely different from each other, although associated together. These actions lead to the manifestation of intelligence, sensation, and combined motion, and are dependent on the vitality of complex organs,—viz., the brain, spinal cord, and nerves. But as the connection between these cannot be shown to exhibit such an order of functional sequence as has been made apparent among the nutritive processes, it will be necessary to describe them in a different manner.

General Arrangement of the Nervous System.

To the eye, the nervous system appears to be composed of two structures—the gray or ganglionic, and the white or fibrous. The ganglionic, when examined under high powers, may be seen to be composed of nucleated cells, varying greatly in size and shape, mingled with a greater or less number of nerve-tubes, also varying in calibre. The fibres, as we have previously seen, consist of minute tubes. There are also bundles of gelatinous or flat fibres, the nature of which is much disputed, very common in the olfactory nerve and sympathetic system of nerves. There can be no doubt that some nerve-tubes run into the ganglionic corpuscles, whilst others originate from them. It is also now rendered certain that the same ganglionic cell may receive and give off nerve-tubes, each having distinct properties, the one of conveying the influence of impressions to, and the other of conveying influences from, the nervous centres.

The general arrangement of the two kinds of structures should be known. By cerebrum, or brain proper, ought to be understood that part of the encephalon constituting the cerebral lobes, situated above and outside the *corpus callosum;* by the spinal cord, all the parts situated below this great commissure, consisting of *corpora striata, optic thalami. corpora quadrigemina, cerebellum, pons Varolii, medulla oblongata*, and *medulla spinalis.* In this way, we have a cranial and a vertebral portion of the spinal cord.

In the cerebrum, or brain proper, the ganglionic or corpuscular structure is external to the fibrous or tubular. It presents on the surface numerous anfractuosities, whereby a large quantity of matter is capable of being contained in a small space. This crumpled-up sheet of gray substance has been appropriately called the hemispherical ganglion. (Solly.) In the cranial portion of the spinal cord, the gray matter exists in masses, constituting a chain of ganglia at the base of the encephalon, more or less connected with each other and with the white matter of the brain proper above, and the vertebral portion of the cord below. In this last part of the nervous system the gray matter is internal to the white, and assumes the form of the letter X, having two posterior and two anterior cornua,—an arrangement which allows the latter to be distributed in the form of nerve-tubes to all parts of the frame.

The white tubular structure of the vertebral portion of the cord is divided by the anterior and posterior horns of gray matter, together with the anterior and posterior sulci, into three divisions or columns on each side. On tracing these upwards into the *medulla oblongata*, the anterior and middle ones may be seen to decussate there with each other, whilst the posterior columns do not decussate. On tracing the columns up into the cerebral lobes, we observe that the anterior or pyramidal tracts send off a bundle of fibres, which passes below the olivary body, and is lost in the cerebellum (*Arciform band* of Solly). The principal portion of the tract passes through the *corpus striatum*, and anterior portion of the optic thalamus, and is ultimately lost in the white substance of the cerebral hemispheres. The middle column, or olivary tract, may be traced through the substance of the optic thalamus and *corpora quadrigemina*, to be in like manner lost in the cerebral hemispheres. The posterior column, or restiform tract, passes almost entirely to the cerebellum.

In addition to the diverging fibres in the cerebral hemispheres which may be traced from below upwards, connecting the hemispherical ganglion with the structures below, the brain proper also possesses bands of transverse fibres, constituting the commissures connecting the two hemispheres of the brain together, as well as longitudinal fibres connecting the anterior with the posterior lobes. In the spinal cord it results, from the investigations of Lockhart Clarke, that there is a decussation of various bundles of fibres throughout its whole extent. It is now also determined that many of the fibres in the nerves may be traced directly into the gray substance of the cord—a fact originally stated by Grainger, but confirmed by Budge and Kölliker. Further, it has recently been shown that, by means of these fibres, an anastomosis is kept up between the various columns, even those on both sides of the cord, through the medium of nerve-cells in the gray matter; an important fact, principally demonstrated by the labours of Stilling, Remak, Van der Kolk, Schilling, Kupffer, and Owsjannikow.

These later observations, indeed, open up to us the probability that the numerous actions hitherto called *reflex* are truly direct, and are carried on by a series of nervous filaments running in different directions, which have yet to be described. There can be no doubt that they pass and operate through the cord; and hence the term *diastaltic* proposed by Marshall Hall instead of reflex, is in every way more appropriate. The importance of this view appears to us so great, that we refer to the figures on pages 104 and 105, from the Thesis of Owsjannikow,[1] showing the connection of the nerves and ganglionic cells in the spinal cord of a fish, as indicative of probable similar relations yet to be discovered in man.

General Functions of the Nervous System.

The great difference in structure existing between the gray and white matter of the nervous system would, *à priori*, lead to the supposition that they performed separate functions. The theory at present entertained on this point is, that while the gray matter eliminates or evolves nervous power, the white matter simply conducts to and from this ganglionic structure the influences which are sent or originate there.

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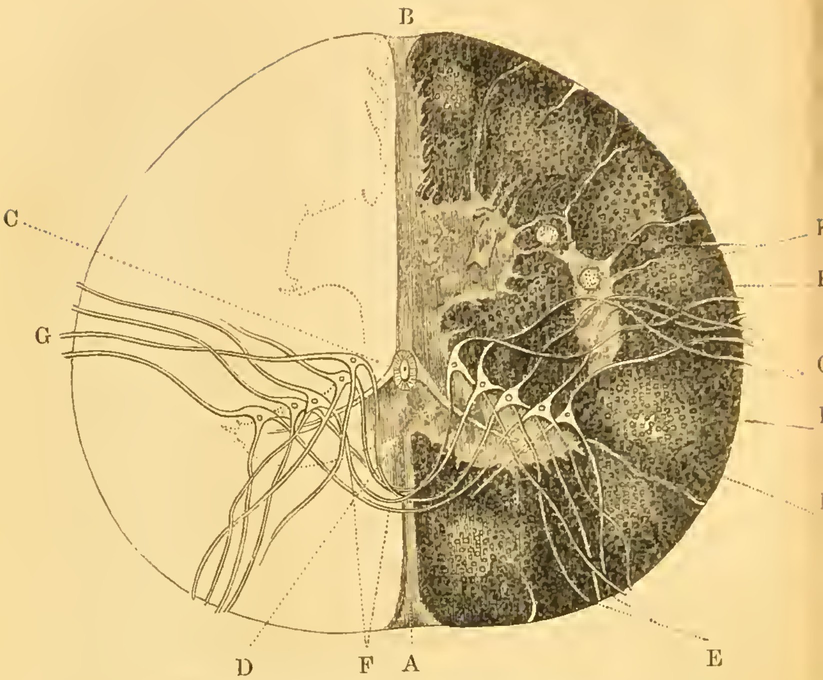
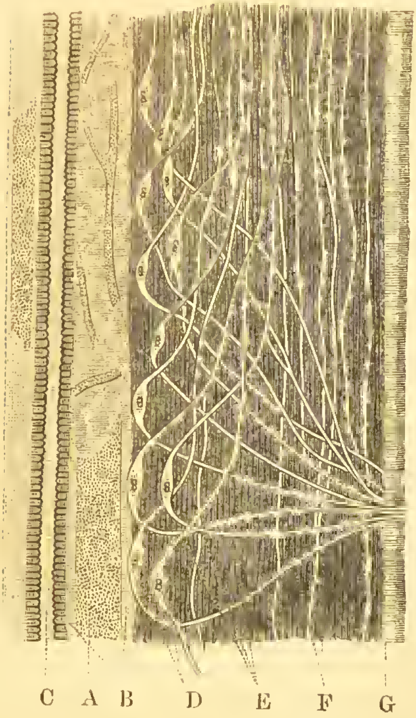
[1] *Disquisitiones Microscopicæ de Medullæ Spinalis Textura*, 1854.



Transverse section of the Spinal Cord of the Salmo salar, about two inches from the Brain, magnified 100 *diameters linear.*

- A. Anterior Groove.
- B. Posterior Groove.
- C. Central Canal lined with Epithelium.
- D. Areolar Tissue surrounding the central canal, continuous with anterior and posterior grooves.
- E. Anterior Root.
- F. Commissural Fibres.
- G. Posterior Root.
- H. Areolar Tissue.
- I. Vertical Fibres of the white substance cut across in the transverse section.
- K. Openings of Blood-Vessels cut across.
- L. Ganglionic Cells.



Longitudinal Section of the Spinal Cord of the Salmo salar, cut obliquely from before inwards, in the course of the fibres of the anterior root.

A. Blood-Vessels filled with Blood Corpuscles.

B. Areolar Texture.

C. Central Canal.

D. Ganglionic Cells.

E. Fibres of the White Substance originating in the cells and going to the brain.

F. Fibres of the Anterior Root which pass through the white substance, and pass into the cells.

G. Pia Mater.

The brain proper furnishes the conditions necessary for the manifestation of the intellectual faculties properly so called, of the emotions and passions, of volition, and is essential to sensation. That the evolution of the power especially connected with mind is dependent on the hemispherical ganglion, is rendered probable by the following facts:—1. In the animal kingdom generally, a correspondence is observed between the quantity of gray matter, depth of convolutions, and the sagacity of the animal. 2. At birth, the gray matter of the cerebrum is very defective; so much so, indeed, that the convolutions are, as it were, in the first stage of their formation, being only marked out by superficial fissures almost confined to the surface of the brain. As the cineritious substance increases, the intelligence becomes developed. 3. The results of experiments by Flourens, Rolando, Hertwig, and others, have shown that, on slicing away the brain, the animal becomes more dull and stupid in proportion to the quantity of cortical substance removed. 4. Clinical observation points out, that in those cases in which the disease has been afterwards found to commence at the circumference of the brain, and proceed towards the centre, the mental faculties are affected *first;* whereas in those diseases which commence at the central parts of the organ, and proceed towards the circumference, they are affected *last.*

The white tubular matter of the brain proper serves, by means of the diverging fibres, to conduct the influences originating in the hemispherical ganglion to the nerves of the head and trunk, whilst they also conduct the influence of impressions made on the trunk, in an inverse manner, up to the cerebral convolutions. The other transverse and longitudinal fibres which connect together the two hemispheres, and various parts of the hemispherical ganglion, are probably subservient to that combination of the mental faculties which characterizes thought.

The spinal cord, both in its cranial and vertebral portions, furnishes the conditions necessary for combined movements; and that the nervous power necessary for this purpose depends upon the gray matter is rendered probable by the following facts:—1*st*, Its universal connection with all motor nerves. 2*d*, Its increased quantity in those portions of the spinal cord from whence issue large nervous trunks. 3*d*, Its collection in masses at the origin of such nerves in the lower animals as furnish peculiar organs requiring a large quantity of nervous power, as in the *Triglia volitans*, *Raia torpedo*, *Silurus*, &c. 4*th*, Clinical observation points out that, in cases where the central portion of the cord is affected previous to the external portion, an individual retains the sensibility of, and power of moving, the limbs, but wants the power to stand, walk, or keep himself erect, especially when the eyes are shut; whereas, when diseases commence in the meninges of the cord, or, externally, pain, twitchings, spasms, numbness, or paralysis, are the first symptoms present, dependent on lesion of the white conducting matter.

The white matter of the cord acts as a conductor, in the same manner that it does in the brain proper, and there can be no doubt that the influence arising from impressions is carried not only along the fibres, formerly noticed, which connect the brain and two portions of the spinal cord together, but along those more recently discovered, which decussate or anastomose in the cord itself (Brown-Sequard), and are connected with the ganglionic cells of the gray matter.

The various nerves of the body consist for the most part of nerve-tubes running in parallel lines. Yet some contain ganglionic corpuscles, as the olfactory and the ultimate expansion of the optic and auditory nerves; whilst the sympathetic nerve contains in various places not only ganglia, but gelatinous flat fibres. The posterior roots of the spinal nerves possess a ganglion, the function of which is quite unknown. These roots are connected with the posterior horn of gray matter in the cord, while the anterior roots are connected with the anterior horns. As regards function, the nerves may be considered as—1*st*, Nerves of special sensation, such as the olfactory, optic, auditory, part of the glosso-pharyngeal and lingual branch of the fifth. 2*d*, Nerves of common sensation, such as the greater portion of the fifth, and part of the glosso-pharyngeal. 3*d*, Nerves of motion, such as the third, fourth, lesser division of the fifth, sixth, facial, or *portio dura* of the seventh, and the hypo-glossal. 4*th*, Senso-motory or mixed nerves, such as the pneumo-gastric, third division of the fifth, and the spinal nerves. 5*th*, Sympathetic nerves, including the numerous ganglionic nerves of the head, thorax, and abdomen,—the exact function of which has not yet been fully investigated, although they seem to influence the excito-motory and excito-nutrient acts of the internal viscera and organs of sense.

All nerves are endowed with a peculiar vital property called *sensibility*, inherent in their structure, by virtue of which they may be excited on the application of appropriate stimuli, so as to transmit the influence of the impressions they receive to or from the brain, spinal cord, or certain ganglia, that may be considered as nervous centres. The nerves of special sensation convey *to* their nervous centres the influence of impressions caused by odoriferous bodies, by light, sound, and by sapid substances. The nerves of common sensation convey the influence of impressions *to* their nervous centres, caused by mechanical or chemical substances. The nerves of motion carry *from* the nervous centres the influence of impressions, whether psychical or physical. (Todd.) The mixed nerves carry the influence of stimuli both to and from, combining in themselves sensory and motor filaments. Although the sympathetic nerves also undoubtedly carry the influences of impressions, the direction of these cannot be ascertained, from their numerous anastomoses, as well as from the ganglia scattered over them, all of which act as minute nervous centres. But there *are* cases where certain psychical stimuli (as the emotions) act on organs through these nerves, and where certain diseases (as colic, gallstones, &c.) excite through them sensations of pain.

Sensation may be defined to be *the consciousness of an impression;* and that it may take place, it is necessary,—1*st*, That a stimulus should be applied to a sensitive nerve, which produces an impression; 2*d*, That, in consequence of this impression, a something should be generated we designate an influence, which influence is conducted along the nerve to the hemispherical ganglion; 3*d*, On arriving there, it calls into action that faculty of the mind called consciousness or perception, and sensation is the result. It follows that sensation may be lost by any circumstance which destroys the sensibility of the nerve to impressions; which impedes the process of conducting the influence generated by these impressions; or, lastly, which renders the mind unconscious of them. Illustrations of how sensation may be affected in all these ways must be familiar to every one, from circumstances influencing the ultimate extremity of a nerve, as on exposing the foot to cold; from injury to the spinal cord, by which the communication with the brain is cut off; or from the mind being inattentive, excited, or suspended.

The independent endowment of nerves is remarkably well illustrated by the fact, that whatever be the stimulus which calls their sensibility into action, the same result is occasioned. Mechanical, chemical, galvanic, or other *physical* stimuli, when applied to the course or the extremities of a nerve, cause the very same results as may originate from suggestive ideas, perverted imagination, or other *psychical* stimuli. Thus a chemical irritant, galvanism, or pricking and pinching a nerve of motion, will cause convulsion or spasms of the muscles to which it is distributed. The same stimuli applied to a nerve of common sensation will cause pain, to the optic nerve flashes of light, to the auditory nerve ringing sounds, and to the tip of the tongue peculiar tastes. Again, we have lately had abundant opportunities of witnessing suggestive ideas, or stimuli originating in the mind, induce peculiar effects on the muscles, give rise to pain or insensibility, and cause perversion of all the special senses. (See "Mono-ideism," in a subsequent section.)

Motion is accomplished through the agency of muscles, which are endowed with a peculiar vital property called *contractility*, in the same way that nerve is endowed with the property of sensibility. Contractility may be called into action altogether independent of the nerves (Haller), as by stimulating an isolated muscular fasciculus directly (Weber). It may also be excited by physical or psychical stimuli, operating through the nerves. *Physical* stimuli (as pricking, pinching, galvanism, &c.), applied to the extremities or course of a nerve, may cause convulsions of the parts to which the motor filaments are distributed directly, or they may induce combined movements in other parts of the body *diastaltically* (Marshall Hall),—that is, through the spinal cord. In this latter case the following series of actions take place :—1*st*, The influence of the impression is conducted to the spinal cord by the afferent or *esodic* filaments which enter the gray matter. 2*d*, A motor influence is transmitted outwards by one or more efferent or *exodic* nerves. 3*d*, This stimulates the contractility of the muscles to which the latter are distributed, and motion is the result. *Lastly*, Contractility may be called into action by *psychical* stimuli or mental acts,—such as by the will and by certain emotions. Integrity of the muscular structure alone is necessary for contractile movements ; but also of the spinal cord, for diastaltic or reflex movements; and of the brain proper, for voluntary or emotional movements.

Thus, then, we may consider that the brain acting alone furnishes the conditions necessary for intelligence ; that the spinal cord furnishes the conditions essential for the cooperative movements necessary to the vital functions ; and that the brain and spinal cord acting together furnish the conditions necessary for voluntary motion and sensation.

The following aphorisms will be found useful, in endeavouring to reason correctly on the functions of the nervous system :—

1. The brain proper is that portion of the encephalon situated above the *corpus callosum*.

2. The spinal cord is divided into a cranial and a vertebral portion.

3. The gray matter evolves, and the white conducts, nervous power.

4. *Contractility* is the property peculiar to fibrous texture, whereby it is capable of shortening its fibres. Motion is of three kinds—*contractile*, dependent on muscle ; *diastaltic*, dependent on muscle and spinal cord ; *voluntary*, dependent on muscle, spinal cord, and brain.

5. *Sensibility* is the property peculiar to nervous texture,

whereby it is capable of receiving impressions. *Sensation* is the consciousness of receiving such impressions.

Senso-Motory Electrical Phenomena.—The manner in which the nervous force is generated and conducted along the nerves to distant parts of the body has given rise to the idea that it resembles electricity. But that there is any identity between them is disproved by the following facts:—1. The firm application of a ligature to a nerve stops the propagation of the nervous influence below the point of application, but not of electricity. Indeed, the nervous trunk is as good a conductor of electricity after as it was before the application of the ligature. 2. If a small piece of a nervous trunk be cut out, and replaced by an electric conductor, electricity will still pass along the nerve; but no nervous force, excited by the strongest irritation above the section will be propagated through the conductor to the parts below. 3. A nerve is not so good a conductor of electricity as some other tissues. Matteuci assigns to muscles a conducting power four times greater than that of nerve or cerebral matter; and from the results of some experiments by Dr Todd, with the most delicate instruments, he concludes that both nerve and muscle are infinitely worse conductors than copper. In fact, their power of conduction does not rank above that of water holding in solution a small quantity of saline matter. 4. That in all those animals which undoubtedly evolve electricity, a peculiar apparatus, resembling a series of galvanic piles, is superadded, proving that other conditions are required than those ordinarily existing in the nervous system to produce the electric force. In the present state of science, therefore, facts are opposed to the idea of nervous power being identical with electricity. It is very possible, however, that future observations may prove one to be a modification of the other. It should not be forgotten that it is only lately that the relations have been discovered which exist between electricity, galvanism, and magnetism; and, as Mr Faraday remarks, "If there be reason for supposing that magnetism is a higher relation of force than electricity, so it may well be imagined that the nervous power may be still more of an exalted character, and yet within the reach of experiment."

Dr Todd considers that the change which takes place in nerve during its excitation is analogous to that which occurs in the particles of a piece of soft iron, in virtue of which the iron acquires the properties of a magnet so long as it is maintained in a certain relation to a galvanic current—the magnetic power being instantly communicated when the circuit is completed, and as rapidly removed when it is interrupted. He considers that a similar *state of polarity* of the particles of a nerve, when stimulated, may be induced. This polar state, he thinks, may be occasioned in tissues, either muscular or nervous, with which the nerve stimulated may be in organic connection; just as the polar state of the electrical apparatus is capable of being communicated to the piece of soft iron, which thereby acquires the well-known magnetic properties during the continuance of the excited polarity. This analogy may be admitted, although it has in noway been proved that what is here called *nervous polarity* is in any way identical with electrical or magnetic polarity. Some animals, as the glow-worm, fire-fly, and others, generate light, which, like the evolution of electricity, is connected with the presence of a peculiar organ or apparatus. It cannot be maintained that light and nervous influence are the same; and we are therefore compelled to conclude, that the generation both of electricity and light in animals is a vital property special to peculiar organs, which, like other vital properties, though connected with, and influenced by, the nervous system, is altogether distinct from it.

Several fishes, but more especially the genera Torpedo, Gymnotus, and Malapterurus, give out electrical shocks when touched or irritated, which gradually become weaker, and cease altogether from frequent repetition, but return after a certain period of repose. The agent producing these has been proved to be electricity, by being communicable to chains of individuals, by causing chemical decomposition, and a luminous spark on its sudden discharge. It is isolated by non-conductors, deflects the magnetic needle, and communicates magnetic properties to soft iron when transmitted through a coil of wire surrounding it. The discharge of the gymnotus has been estimated to be equal to that of a battery of Leyden jars of 3500 square inches, fully charged. We can have no doubt, therefore, that an animal can generate electricity, and discharge it at will, for the purpose of stupifying or killing other creatures, or as a result of reflex nervous action, whilst its own body is entirely free from the sensitive and motor consequences of the shocks which it produces. The electrical organ in these animals consist of piles of very numerous and closely-set thin membranous plates, among which numerous fine nerves are distributed. Between these plates are small cavities filled with an albuminous fluid; so that the apparatus closely resembles a number of moist galvanic piles or batteries closely aggregated together. This structure, though differently arranged in the various kinds of fish, is richly supplied by motor and sensitive nerves and by blood-vessels. The nerves are distributed on one surface only of the plates, whilst the blood-vessels go to another, on which nucleated cells are listributed. (Pacini.) There is also a special lobe of the brain situated on the *medulla oblongata*, close to the origin of the vagus nerve, which is called the *electric lobe*. It contains large ganglionic corpuscles from which nerve-tubes arise. When this lobe is destroyed, the power of generating electricity is destroyed with it; whereas the whole brain above it may be removed without immediately impairing the function of the batteries. This fact has led some to suppose that the electricity is generated in the brain; but there can be little doubt that it is formed in the batteries, which, however, differ in different animals. Thus, in the torpedo the action resembles that of a thermo-electric pile,—the nerve and vascular surfaces corresponding to the bismuth and copper elements, whilst the nervous influence corresponds with heat. When, therefore, a shock is induced in the torpedo, either voluntarily or by reflex action, the nervous influence sent to one surface of the electrical plate throws the other into an opposite electrical condition, and a current is the consequence. In the gymnotus, on the other hand, the apparatus has been compared to the hollow cylinder of porous clay, which, in a Bunsen's or Grove's galvanic arrangement, separates the negative from the positive elements. (Pacini.)

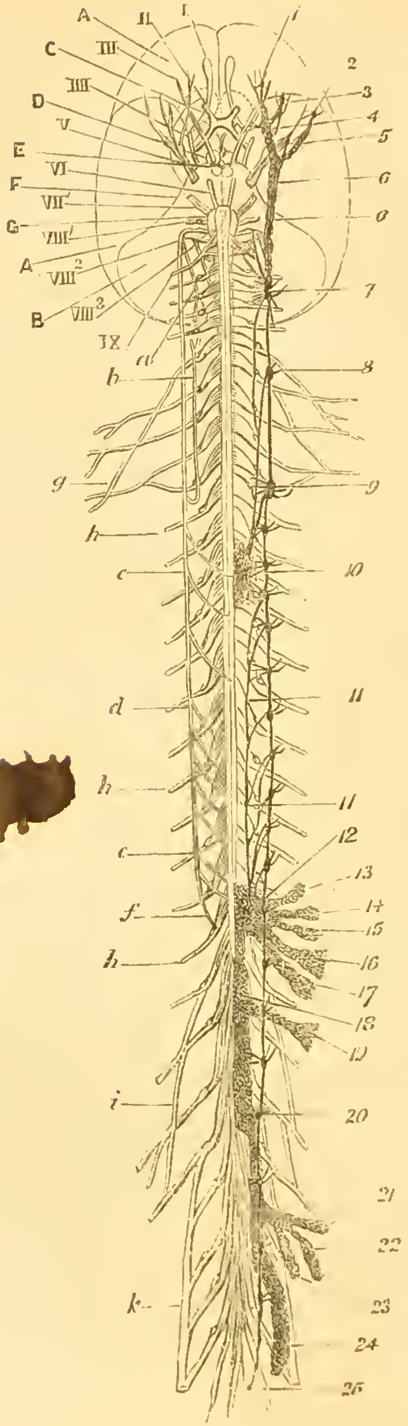
Although in other animals little electricity seems to be generated, electric currents have been demonstrated in the muscles and in the nerves. Galvani first noticed the fact, that when the exposed muscles of a frog's limb are brought into contact with the sciatic nerve, the muscles are slightly contracted. Nobili found that when the circuit of the nerve and muscles was closed by a galvanometer, a deviation of the needle took place to the extent of 10°, 20°, or 30°, in consequence of a current which passed in the limb from the toes upwards, and which could be increased by inclosing in the circuit several frogs arranged as a battery. Matteuci showed that these currents were independent of the nervous texture; and Du Bois-Reymond that the longitudinal section of a muscle, natural or artificial, is invariably positive to the transverse one. According to him, the muscular substance during life, and in the intervals of contraction, is in a state of electric tension, which is much diminished, or disappears during its action. He succeeded in showing this experimentally in the human subject. The fore-fingers of a muscular individual being dipped in a saline solution, together with the electrodes of the galvanometer, no deflexion of the needle occurs. If all the muscles of one arm be now strongly and continuously contracted, a current is indicated passing from the finger to the shoulder in the contracted arm, and in the opposite direction in the relaxed one. Other experiments showed,—1*st*, That the current varies in different individual muscles, in some running from the head to the foot, in others in the opposite direction; 2*d*, That the electro-motor power of a muscle is directly as its length and thickness; and 3*d*, That if two muscles are opposed to one another in a circuit, the thicker or the longer overcomes the other. Hence the current in one entire organism represents the superior force of the currents of the stronger muscles. As regards nerve, Matteuci failed in detecting any electrical current in it; but Du Bois-Reymond has done so by employing a very delicate galvanometer. He has determined that the nervous electric current has the same relation to the longitudinal and transverse sections as is observed in muscle, and that in this respect all the nerves are alike. It would also appear from his observations, that when a nerve is completely excited or tetanized by electricity, its usual electro-motor power is diminished, or in abeyance, and that a similar loss accompanies intense functional excitement from ordinary agents. No difference as to electrical relations exist between motor and sensory nerves, and in both kinds innervation advances in either direction with equal facility. The muscles, when they are caused to contract in consequence of electricity sent along a nerve, do so only at the opening and closing of the circuit. From these researches it would appear, that in an organized being electrical currents are induced by arrangements of its fluids, textures, and organs, although the physiological importance of these remains to be discovered. It must be clear, however, that such currents are intimately connected with the normal functions of the parts which exhibit them, a circumstance which indicates the advantage of applied electricity in various paralytic and spasmodic diseases. This subject is now being investigated on scientific rather than on empirical grounds, especially by Remak.

Special Functions of the Nervous System.

On proceeding to determine more closely what are the special functions of the individual parts of the nervous system, we should never forget that the various ways in which they have been investigated have led to opposing results, and that such is the excessive difficulty of the inquiry, that we should be especially on our guard against specious hypotheses and unfounded theories. Anatomy, human and comparative, has furnished us with many valuable facts; but it is not easy to determine what are the nervous ganglia or other parts in the lower animals which correspond with what exists in man; whilst erroneous interpretations as to the habits and motions of these creatures are too readily formed. Again, in making experiments on animals, it is often impossible to ascertain how far the shock of the operation, the flow of blood, or the destruction of other parts may vitiate the results. Lastly, an observation of the effects of disease often leaves us in doubt how far the organic mischief extends, and what phenomena may be rightly attributed to it, and what to the congestion of the blood-vessels which accompany it. This last, however, is by far the most important means of research open to us; and if to the result of pathological observation, a similar one is obtained from well-performed experiments, our views derived from either will be confirmed. If to this, anatomy reveals such connections as will warrant and bear out such conclusions, we may consider that every proof is given which conviction requires. It should be remembered, therefore, that such is the fallacy inherent in each individual method of research that little dependence can be placed upon it, and that at least two of these must be united to give probability to any given theory.

Functions of the Cerebral Lobes.—The cerebral lobes (diagram, A, A, A, p. 130), as has been previously stated, are undoubtedly concerned in the evolution and manifestation of intellect. This result is supported by every known mode of investigation, which also indicates that the former depends on the cortical, and the latter on the conducting or tubular portion. Further than this we are not warranted in going, for the facts which establish these great conclusions entirely negative all those theories which have been advanced having for their object a localization of the different faculties into which the mind has been arbitrarily divided. When, indeed, we endeavour to analyse these, and separate the reasoning powers from instinctive actions, the difficulty of the inquiry seems at first to be overwhelming. To analyse the intricate combinations of our own minds is a difficult task; but how much more laborious is it to study the variations in the minds of others, and to investigate the habits of the countless tribes of animals with the view of distinguishing which depend on reason, and which on blind instinct! The attempts of metaphysicians in this direction are not satisfactory. According to them, however, the purely mental faculties are,—Consciousness, Perception, Attention, Conception, Abstraction, Association of Ideas, Memory, Imagination, and Judgment or Reasoning. To these may be added the Affections, Desires, Self-love, and the Moral Faculty. (Stewart.)

Gall and Spurzheim have divided mind into thirty-three faculties, to which Mr Combe added two more, making thirty-five in all. These are—1*st*, *Amativeness*; 2*d*, *Philoprogenitiveness*, or love of offspring; 3*d*, *Concentrativeness*, or the power of continuing impressions and ideas; 4*th*, *Adhesiveness*, or the desire to attach ourselves to persons or objects; 5*th*, *Combativeness*, or the inclination to fight and be embroiled in contentions; 6*th*, *Destructiveness*, or the desire of destroying life; 7*th*, *Constructiveness*, or a disposition to apply oneself to the mechanical arts; 8*th*, *Covetousness*, or the desire to covet, to amass, or acquire; 9*th*, *Secretiveness*, to conceal; 10*th*, *Self-Esteem*, or self-love; 11*th*, *Love of Approbation*, or the pleasure we derive from the commendations we receive from others; 12*th*, *Cautiousness*; 13*th*, *Benevolence*, or meekness and gentleness of disposition; 14*th*, *Veneration*, by which we worship the Deity and material objects; 15*th*, *Hope;* 16*th*, *Ideality*, or the poetical disposition; 17*th*, the faculty of *Conscientiousness*, or of justice and equality; 18*th*, *Determinativeness*, or firmness of character or purpose; 19*th*, *Individuality*, or the power we possess of knowing external things; 20*th*, *Form*, by which we take cognisance of the forms of external objects; 21*st*, *Size*, that power which seizes hold of dimensions; 22*d*, *Weight*, that faculty by which we estimate weight, density, resistance, &c.; 23*d*, *Colour*, the faculty of perceiving colours; 24*th*, *Space* or *Locality*, the power of local memory; 25*th*, *Order*, or a love of methodical arrangement; 26*th*, *Time*, or the faculty which enters into speculations on duration; 27*th*, *Number*, or the power of calcu-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VIEW OF THE NERVOUS SYSTEM IN MAN.

A,A,A. Cerebral Lobes—B. Cerebellum—C. Corpus Striatum—D. Optic Thalamus—E. Corpora Quadrigemina—F. Pons Varolii—G. Medulla Oblongata—H, H. Spinal Cord.

LEFT SIDE.—*The Cerebro-Spinal System of Nerves.*

I. Olfactory, or first pair of Nerves—II. Optic, or second pair of Nerves—III. Motor Nerves of Eyeball, or third pair of Nerves—IV. Pathetic, or fourth pair of Nerves—V. Trifacial, or fifth pair of Nerves—VI. Abducent, or sixth pair of Nerves—VII. Facial and Auditory, or seventh pair of Nerves—VIII. (1.) Glossopharyngeal Nerve—VIII. (2.) Pneumo-gastric Nerve, or Vagus—VIII. (3.) Spinal Accessory Nerve—IX. Hypoglossal, or ninth pair of Nerves—From *a* to *f*. Branches of the Vagus: *a*. Superior Laryngeal Nerve; *b*. Inferior Laryngeal Nerve; *c*. Cardiac and Pulmonary branches of the Vagus; *d*. Œsophageal branches of the Vagus: *e*. Gastric branches of the Vagu[illegible] Termination of the Vagus on the right side in the solar g[illegible]chial Plexus—*h, h, h*. Spinal Nerves—*i*. Iliac Plexus—[illegible]al Plexus.

RIGHT SIDE.—*The Sympathetic or Ganglionic System of Nerves.*

1. Ophthalmic Ganglion—2. Submaxillary Ganglion—3. Spheno-palatine Ganglion—4. Cavernous Plexus—5. Otic Ganglion—6, 6. Carotid Plexus, surrounding the carotid artery—7. Super-cervical Ganglion—8. Middle Cervical Ganglion—9. Inferior Cervical Ganglion—10. Cardiac and Pulmonary Plexuses—11, 11. Splanchnic Nerves—12. Solar Ganglion—13. Hepatic Plexus—14. Gastric Plexus—15. Splenic Plexus—16. Super-mesenteric Plexus—17. Renal Plexus—18. Aortic Plexus—19. Inferior Mesenteric Plexus—20. Hypogastric Plexus—21. Inferior Hypogastric Plexus—22. Ovarian Plexus—23. Uterine Plexus—24. Vesical Plexus—25. Ganglion Impar.

lation; 28*th*, *Tune*, or the perception of musical tone; 29*th*, *Language*, the faculty by which we learn artificial signs; 30*th*, *Comparison*, by which we recognise differences, analogies, similitudes, &c.; 31*st*, *Causality*, that power which directs our attention to the causes of things; 32*d*, *Wit*, the faculty of jesting, raillery, mocking, &c.; 33*d*, *Imitation*, the power of imitating sounds, gestures, manners, &c. These are the several faculties of mind laid down by Drs Gall and Spurzheim; but to this catalogue Mr Combe has added two others,—34*th*, *Wonder*, or that which relates to the marvellous, supernatural, &c.; and 35*th*, *Eventuality*, or that which takes cognisance of changes, events, and active phenomena.

The objections to this division of the mental faculties are,—1*st*, Its complexity; and, according to the phrenological system, one faculty is considerably influenced by others; so that compound characters may be easily manufactured at will, and thus numerous sources of fallacy thrown open. 2*d*, It is redundant in some faculties, and deficient in others. It is redundant, for instance, in having two organs for Form and Size, for Combativeness and Destructiveness, for Causality and Concentrativeness. Each of these two, if not identical, are, at all events, closely allied. It is deficient in having no such faculties as Memory, Reasoning, and Judgment, which every man is conscious he possesses. But it is said every organ has a power of remembering, reasoning, and judging; so that there are other faculties which govern or attend upon all the thirty-five organs. There are also obvious deficiencies in the propensities or instincts; for mankind not only love, steal, fight, kill, secrete, and build, but run, swim, walk, talk, sing, learn, and so on, which have no place in the phrenological system. Perhaps there is no instinct so strong in man and animals as that of self-preservation, and yet this has no organ ascribed to it by the phrenologists. As a philosophical and metaphysical system of the mental faculties, therefore, the classifications of Stewart and Brown seem to us greatly superior, especially in all the higher properties of the intellect; although, so far as the instincts and passions are concerned, they are, perhaps, inferior.

If our knowledge of what the faculties of the mind really are, and how they should be divided, is so imperfect, it may appear unnecessary to attempt to determine in what part of the brain each is situated. As might be expected, all such efforts have failed. That the brain furnishes the conditions necessary for the evolution and manifestation of mind, we have seen is established; and that the gray matter originates, whilst the white matter conducts, the influences generated, we have also shown to be highly probable. But we have no facts which point out that Memory, Consciousness, Judgment, Reasoning, or similar faculties belong to one part of the cerebral convolutions more than to another. Gall and his followers have localized all the thirty-five faculties into which they have divided the mind. He observed that certain individuals who displayed mental powers, moral feelings, or particular propensities, had a fulness or prominence in a certain part of the anterior, middle, or posterior third of the cranium. By paying attention to the principal characteristics of remarkable men, and the living habits of animals, he found that this fulness or prominence coincided in a number of cases; and he concluded from this that the function of brain which existed below the prominence was the organ giving rise to the characteristic faculty. He then sought to confirm his theory by anatomy, physiology, and pathology; and he and his disciples have accumulated an immense number of these coincidences, which they believe sufficient to establish the phrenological theory.

But, proceeding on the principles which the phrenologists themselves have laid down, it is easy to show that the exceptions are as numerous as the coincidences; whilst the other modes of inquiry to which we have alluded,—namely, anatomy, the results of experiments on living animals, and the observations of the symptoms of disease as compared with the appearances presented after death,—not only give no support, but are directly opposed to the views of Gall. Thus, some remarkable skulls in the museum of the university of Edinburgh are, on the principles of the phrenologists themselves, entirely opposed to their doctrines. Of these, among many, we would point to the skulls of Burke, Pepé, and Haggart,—the two former remarkable murderers, with Destructiveness small; and the latter a most dexterous thief, with Acquisitiveness small. Anatomy proves that, while the lower vertebrate animals possess the anterior and middle lobes of the brain well developed, which are said to be the seat of the intellectual faculties and moral sentiments, they are deficient in those parts where Love of Offspring, Adhesiveness, Destructiveness, and Combativeness are found,—facts wholly incompatible with the theory of Gall. In the same manner, the great majority of facts derived from physiological and pathological research give no support to phrenology. Although, therefore, this doctrine is unquestionably founded upon a large number of data, it cannot lay claim to a correct localization of the mental faculties in any way superior to other systems, which, like it, have been advanced by ingenious men, excited attention for a season, and ultimately abandoned as inconsistent with the present state of our knowledge. The names of Gall, Spurzheim, and Combe, notwithstanding, ought ever to be registered among those whose labours have greatly contributed to advance our knowledge of the physiology of the brain.

Function of the Cerebellum, Corpora Striata, Optic

Thalami, and Corpora Quadrigemina.—These different parts of the encephalon contain masses of ganglionic matter differently arranged, connected with the spinal cord below and the cerebrum above. We have as yet no means of determining with certainty the functions of each ganglion, although it is probable that the cerebellum (diagram, B, p. 120) is connected with the power of voluntary combined movements, and the *corpora quadrigemina* (diagram, E) with the sense of sight, but not exclusively so; for the *corpus striatum* (diagram, C) is also connected with the one, and the optic thalamus (diagram, D) with the other. The whole, perhaps, may be regarded as uniting together the diastaltic function in connection with the head and face; and hence, as being an extension in another form of the gray matter of the spinal cord into the encephalon.

Function of the Pons Varolii and Medulla Oblongata (Diagram, F, G, p. 120).—These portions of the encephalon possess the same function as the spinal cord, with the addition of being more essential to life, on account of their being the centres (especially the latter) which furnish the necessary power for maintaining the co-ordinate movements of respiration and deglutition. It is by arresting respiration, and paralysing the functions of the important organs to which the vagi nerves are distributed, that sudden injury to the *medulla oblongata* proves so rapidly fatal.

Function of the Spinal Cord (Diagram, H, H).—This nervous centre receives and gives off the different nerves which go to all parts of the body, and is the organ necessary for combined motions, and conducting the sensitive influences essential to sensation. These influences are now known, principally from the experimental researches of Brown-Sequard, to be conducted through the gray matter by means of nerve-tubes connected with the ganglionic cells. If the influences reach the cerebral convolutions, and excite consciousness, sensation is the result. If the influences originating in these convolutions, by an act of volition, pass outwards to a special series of muscles, voluntary motion is produced. But numerous combined muscular actions may go on independent of volition or sensation, and even when the brain is removed. These depend on influences originating in physical irritations applied to an incident nerve, which are conducted through the spinal cord, and from it by excident nerves to the muscles, the contractility of which is thereby excited. The character of these movements gave rise to the idea that they were connected with sensation, and indicated pain. Thus, decapitated animals may be seen to struggle exactly as they would do were the brain entire. They endeavour to avoid the particular injury, push the irritating instrument away with their paws, and writhe as if in agony; so that it is exceedingly difficult for a spectator to convince himself that they are not suffering, and that such motions are not connected with sensation. But we have previously seen, and the slightest analysis of our own sensations and mental operations will soon convince us, that sensation is the *consciousness* of an impression. If then the same sensitive and motor phenomena are produced independent of brain as when it is present, we must either believe that consciousness resides in the spinal marrow, and that therefore they are connected with sensation, or that it resides in the brain, in which case they must be independent of sensation. The former was the notion of Whytt, Haller, Le Gallois, Prochaska, and others, who connected these spinal movements with a so-called *sensorium commune.* It was Dr Marshall Hall who first clearly separated these functions from cerebral or mental acts, and placed them altogether in the spinal cord. He pointed out that they were independent of mind, and *therefore* not connected with sensation. He classified them by themselves, under the name of reflex, excito-motory, or diastaltic actions; described the laws by which they are governed, and their universal application to the pathology and diagnosis of disease. We have previously seen that all such actions require a centre with incident and excident nerves communicating with it, although the exact relation of these, as explanatory of individual diastaltic movements, has not yet been determined.

As examples of diastaltic or purely spinal motions, may be enumerated,—1*st*, Those constantly going on in the eyelids when any object approaches them, in which case the incident nerve is the palpebral branch of the fifth, and the excident the orbicular branch of the seventh pair of nerves. 2*d*, The closure of the larynx in every act of deglutition, and in every effort to vomit, and as occurs on the contact of a drop of water or a crumb of bread, &c., when the incident nerve is the superior and the excident the inferior laryngeal. 3*d*, The various movements associated in the act of respiration, in which the incident nerves are the sensitive branches of the fifth pair, of the pneumogastric and spinal nerves, while the excident are the spinal accessory and motor portions of the intercostal, diaphragmatic, and lower spinal. 4*th*, The different actions associated in the act of swallowing, including those that occur in the pharynx, œsophagus, and the cardiac orifice of the stomach. The incident nerves are united with the excident in the pharyngeal, œsophageal, and cardiac branches of the pneumo-gastric. 5*th*, Numerous actions connected with the outlets of the body, as in defœcation and expulsion from the urinary and generative organs, in which the incident and excident nerves are united in the branches of the spinal nerves. 6*th*, The movements of the fœtus *in utero*. 7*th*, Numerous complex actions, acquired at one period, and performed afterwards automatically, without exercise of mind, such as walking, playing certain pieces of music on various instruments, &c. 8*th*, Instinctive actions of various animals, as the flying of migratory birds, building their nests, construction of the honey-comb, &c. 9*th*, All the spasmodic and convulsive actions of the body, including vomiting, choking from the presence of a foreign body in the larynx or pharynx, nervous twitching of the limbs, convulsions of parts of the whole body in chorea, hysteria, epilepsy, and rigid spasms of tetanus, &c. &c. In these four last kinds of actions, the sensitive nerves of various parts of the body are the incident, and the motor the excident nerves.

These diastaltic actions, though spinal and independent of mind, may, to a certain extent, be controlled by the will. Thus the sudden contact of hot or cold bodies to the skin, the prick of a pin, &c., if unexpected, will cause starting; but if a resolution be formed not to do so, this effect may be prevented. This influence is exercised over different muscles in different degrees; and it varies in persons from constitutional and unknown causes. Other spinal actions apparently require the co-operation of the mind, such as coughing, sneezing, laughing, sobbing, yawning, and hiccough. In these cases it frequently happens that the most determined effort of the will fails to control them; whilst arresting or withdrawing the attention checks them at once. Hence we have one class of motions purely voluntary, and another partly voluntary and partly spinal, such as coughing, laughing, sneezing, &c., which it is difficult to conceive being produced without a certain mental effort. Then we have a class of motions altogether involuntary, wholly spinal, which may be carried on for a certain time in a decapitated animal.

Functions of the Cerebro-Spinal Nerves.—There are generally enumerated, after Willis, nine cerebral pairs and thirty-one spinal pairs of nerves. (See left side of diagram, p. 120.) All the so-called cerebral nerves, with the exception of the first pair, which is in truth a ganglion, may be regarded as belonging to the cranial portion of the spinal cord. The first pair of nerves, called the *olfactory*, serve to receive and convey the influences excited by odours on the Schneiderean membrane of the nose, to which it is distributed, direct to the brain, to produce the sensation of smell. The second pair, or *optic* nerves, receive and convey to the brain the influences excited by light, so as to produce the sensation of sight. The third pair of nerves, or the *motor nerves of the eyeball*, are purely motor, and regulate all the movements of the eyeball, except those which depend on the external rectus and superior oblique muscles. The fourth pair of nerves, or *pathetic*, also called *trochlear*, are purely motor, and govern the movements of the trochlearis, or oblique muscle of the eye. The fifth pair of nerves, called *trifacial* or *trigeminal*, divide into three branches,—two of which are purely sensitive, and the third is senso-motory. The sensitive branches terminate in the face, and communicate sensibility to the skin, various organs of the head, and to the external parts of the organs of special sense. It is also the great excitor nerve of these parts. Its communications also with the ganglia of the sympathetic system render its integrity of the greatest importance to various excito-motory, excito-sensory, and excito-nutrient actions of the head and face. The non-ganglionic branch distributed to the muscles of the jaws is motor, and governs the movements of mastication. The sixth pair of nerves, called *abducent*, are motor, and govern the motions of the external rectus muscle of the eyeball. The seventh pair of nerves are composed of two parts, which are really separate nerves. The hard portion, or *facial nerve*, is motor, and governs the movements of all the muscles of the face. The soft portion, or *auditory nerve*, transmits the influences of sound through the internal ear to the brain, to produce the sensation of hearing. The eighth pair of nerves are divided into three branches,—1*st*, The *glosso-pharyngeal*, distributed to the root of the tongue and pharynx, is a nerve of sensibility, administering to taste and touch in the former situation, while it is the great excitor in the act of deglutition in the latter. 2*d*, The second branch is the *par vagum*, or *pneumo-gastric* nerve, and is distributed to numerous important parts, its branches having different functions. As a whole, it is a motor and sensitive nerve, and contains incident and excident filaments. The pharyngeal and inferior laryngeal branches are wholly motor; its superior laryngeal branch is the sensitive nerve of the larynx, but is mixed with a few motor filaments, which supply the crico-thyroid muscle; the cardiac, pulmonary, œsophageal, and gastric branches are senso-motory. It also forms most important connections with the sympathetic system of nerves; and, like the fifth, is instrumental to numerous excito-motory, excito-secretory, and excito-nutrient functions of the neck, chest, and abdomen. 3*d*, The third branch of the eighth pair, or *spinal accessory*, is a motor nerve, the external division supplying the external muscles of respiration; the sterno-mastoid and trapezius, and the internal division, adding motor filaments to the vagus. The ninth pair of nerves, or *hypo-glossal*, is the motor nerve of the tongue. There are thirty-one pairs of spinal nerves, all of which are senso-motory,—the posterior ganglionic root being sensory, and the anterior motor.

These, united, form a compound nerve, containing sensitive and motor filaments neccssary for sensation and combined motions, including incident and excident filaments in connection with distinct portions or arcs of the spinal cord as centres of diastaltic movements.

Functions of the Sympathetic Nerves.—This system of nerves has also been called *ganglionic*, *organic*, and *trisplanchnic.* It consists essentially of a number of ganglia containing numerous nerve-cells, communicating by one series of connecting nerve-tubes with each other, and by another series with the cerebro-spinal nerves. (See right side of diagram, p. 120.) The ganglia are arranged, according to their situation, into cephalic, cervical, thoracic, and abdominal; while the connecting filaments forming plexuses have received numerous names in different parts, such as carotid, cardiac, diaphragmatic, supra-renal, hepatic, splenic, superior and inferior mesenteric, &c. &c. The connection between the cerebro-spinal nerves and those of the sympathetic system is indirect through ganglia, which break the conducting power of the nerves or modify it,—probably both. Under ordinary circumstances, no act of volition or of the mind can induce movements in parts supplied by the sympathetic; but under peculiar circumstances, or under the influence of unusual stimuli, movements are induced. Thus the emotions and desires, shame or fear, influence the movements of the heart and the contractile power of the capillaries, which an effort of volition cannot do. Such results are only explicable by the connection of the sympathetic system with nerves coming direct from the brain. Direct irritation of the sympathetic ganglia will also cause movements in the non-voluntary muscular parts receiving filaments from them. In the same way, for the most part, the internal organs and surfaces supplied by these nerves are not endowed with ordinary sensibility, and the mind is unconscious of their action; but occasionally very severe pain is produced from their being the seat of disease, as in certain agonizing pains of the heart (*angina pectoris*), in the intestines (*colic*), in the stomach, liver, kidneys, &c. &c. Thus, although in health the sympathetic system so diffuses the influences conducted that they are not obedient to or excite mental acts, there is abundant proof that the cerebro-spinal filaments passing through the ganglia are constantly operating, although insensibly, in subjection to the cerebro-spinal centres. The ganglia, however, not only diffuse the influence of impressions coming from and sent to the cerebral and spinal centres, but they are nervous centres themselves, and especially centres of numerous reflex acts in non-voluntary muscles.

In addition to this excito-motory function of the sympathetic system, there is another of great importance, recently denominated by Dr Campbell of the United States *excito-secretory*. We have previously seen, however, that secretion in glands is only a form of nutrition; and the influence of this system would appear not only to be exerted on glands, but on blood-vessels and nutrition generally. It is therefore also *excito-nutrient*, and carried on wholly independent of the cerebro-spinal system. Thus it has been shown by Sir B. Brodie that division of the crural and sciatic nerves neither retarded nor impaired wounds and fractures of the inferior extremities; while numerous modern experiments have proved that injury to the large sympathetic ganglia occasion the most destructive effects to the nutrition of the parts which receive nerves from them. The recent experiments of Brown-Sequard and Harley on the supra-renal capsules, have shown that it is difficult to preserve animals if the semilunar or solar ganglion be much injured in the operation; but if this be avoided, animals can live without the supra-renal capsules for a length of time. Again, as illustrative of the general influence of the sympathetic system over nutrition, is the fact that certain fœtuses have been born with well-developed textures, without a brain or spinal cord, in the same manner that many of the lower animals are destitute of these organs.

As local examples of this excito-secretory and excito-nutrient function of the sympathetic system of nerves, may be cited, — 1*st*, The effusion of tears from the lacrymal gland on the application of an irritant. In this case the incident nerve is the palpebral branch of the fifth, and the excident or secretory the lacrymal branches from the carotid plexus. 2*d*, The secretion of saliva on irritation of the gums, or exciting the mouth by food and mastication. Here the incident nerves are the buccal branches of the fifth, and the excident or secretory the parotid branches derived from the carotid plexus. 3*d*, Dentition in infants and children give numerous examples of excito-secretory and excito-nutrient actions. Thus, from tender gums, and irritation of the dental branches of the fifth, the eye may become lacrymose and congested; the Schneiderean membrane congested, and its secretion increased; while diarrhœa is one of the most common symptoms. In these cases the excident nerves are derived from the ciliary and Meckel's ganglia, distributed to the conjunctiva and Schneiderean membranes, and through the splanchnic, with the intestines. 4*th*, The process of lactation exhibits the remarkable influence of excitation applied to the sensitive surface of the nipple. This, when grasped and suction made upon it by the infant, not only occasions increased flow of milk, but causes that peculiar feeling of the rush which mothers describe, and which is apparently owing to congestion of the blood-vessels. Keeping up the flow of milk by constant milking long after it is required for suckling, as is constantly done for domestic purposes among our cattle, is an excellent example of the power of exciting such secretions locally. *5th*, The secretion of starch from the liver, and its ready transformation into sugar, is influenced by irritations of branches of the eighth pair in the lungs, and by direct injury of the pneumo-gastric nerves, through the sympathetic branches of the cœliac and solar plexuses going to the liver. *6th*, The results of section or destruction of the cervical ganglia by Petit, Dupuy, Bernard, and others, and the effects of galvanism applied to the cut extremities of the ganglionic trunks by Brown-Sequard, exhibit how the former injuries cause redness and increased heat in the neighbouring parts, while the latter cause paleness and coldness. This is accomplished in the last experiment by producing contraction or spasm, and in the first by occasioning enlargement and paralysis of the extreme vessels, and thus influencing nutrition. Further examples may be sought in the influence of excitants on all secretions—in the growth of the fœtus *in utero*, the phenomena resulting from shock after injuries, and in numerous diseases, especially of fever, inflammation, cholera, cutaneous eruptions, &c. &c.

It follows that the great functions of the sympathetic system of nerves are,—1*st*, Excito-motory, thereby regulating the contractions of the non-voluntary muscular fibres; 2*d*, Excito-secretory, whereby the various secretions are governed; 3*d*, Excito-nutrient, operating more especially on the blood-vessels, and thereby regulating the circulation in the capillaries.

SPECIAL SENSES.

The nature of sensation has already been dwelt upon; and it has been shown to depend essentially on the existence of mind, or the consciousness of impressions made on the sensitive nerves. The impressions which result from the stimuli of odours, sapid bodies, contact of hard or irritating substances, of light and of sound, are different. For the reception of these also, nerves with peculiar endowments are provided; and to these are added a special structure or organ adapted for the purposes of smell, taste, touch, vision, and hearing. Much discussion has taken place as to whether a sixth sense exists, viz., a muscular sense, or a sense of weight. Two masses of matter apparently similar may be undetectable by sight or touch, but when balanced in the hand, are at once recognised by their difference in weight. Whether this sensation is dependent on the muscles or joints, is doubtful; but that it is distinctive and peculiar, cannot be questioned.

Smell.—The acuteness of scent varies in different animals, and bears a certain relation to the size of the nostrils and turbinated bones, being greater where these are large and extended. Odours which depend on substances suspended in the air, when in an extremely fine state of division, thereby obtain more ready access to the membrane on which the olfactory nerve is distributed. This in animals that live in air is accomplished by the act of inspiration. Hence suspension of respiration prevents the perception of odours; whilst repeated quick inspirations, as in the act of sniffing, renders it more intense and prolonged. It is necessary that the mucous surface covering the expansion of the olfactory nerves should be moderately moist; for if it be too dry on the one hand, or too moist on the other, the sense is impaired or lost. The situation of the sensitive surface high up in the nostrils secures it from the direct contact of air, so as to prevent rapid evaporation and dryness; while the convolutions of the turbinated bones, over which the currents of air pass before reaching the seat of special sense, communicate heat to them, and thus prevent the action of cold. The sense of smell may be exalted, perverted, or lost. It is apparently increased by education, of which the case of James Mitchell is an interesting example. This boy was born blind and deaf, and chiefly depended on smell for keeping up a connection with the external world. He employed it on all occasions, like a domestic dog, in distinguishing persons and things. In some cases smell is exceedingly acute for particular substances, so as to be intolerable and distracting to those who suffer from it. Certain flowers or particular odours have in this way caused fainting or other bodily disorder. In other cases the smell is perverted or diminished, and occasionally is lost, as when the Schneiderean membrane is inflamed, or very rarely from congenital absence of the olfactory nerve.

Taste.—This sense is dependent on the fifth and glosso-pharyngeal nerves,—the former distributed to the two anterior thirds, and the latter to the posterior third of the tongue. This organ is covered over with minute prominences, which, when magnified, present four principal forms, viz.,—1*st*, Simple papillæ; 2*d*, Conical or filiform papillæ; 3*d*, Fungiform papillæ; and 4*th*, Circumvallate or calciform papillæ. It is supposed that the two former are more especially concerned in the sense of touch, with which the tongue is also highly endowed; whilst the two latter, but particularly the last, constitute more especially the apparatus of taste. Sapid bodies pressed against these papillæ give rise to impressions which, when transmitted to the brain, occasion the peculiar sensation. The sense is more acute in some persons than in others; may be rendered more so by education, as is remarkably well observed in wine tasters; and is diminished or lost in febrile or other disorders which alter the condition of the mucous surface of the tongue and mouth.

Touch.—This sense is dependent on the nerves of common sensibility distributed to all parts of the surface. But here also we observe that a distinct structure is necessary for the manifestation of the peculiar property. This consists in the papillæ of the true skin, which are variously modified in different parts of the body, in proportion to the acuteness of the sense. The experiments of Weber and Valentin have shown that the extremity of the third finger and the point of the tongue are the parts most sensitive, as in these places the difference of half a line between the points of a pair of compasses could be distinguished. Next in sensitiveness to these is the mucous surface of the lips, whilst the parts in which touch is least acute are the neck, the middle of the back, and the middle of the arm and thigh. In the papillæ of the fingers and a few other places minute indurated bodies of condensed fibrous tissue have been recently discovered, called the *touch bodies* of Wagner, which have been supposed capable of rendering this sense more acute. They are in immediate relation to a nerve; and the well-known effects of pressing such nerve against a hard body, as in the case of a corn, may well be supposed capable of exalting the sensibility.

Sight.—This sense is dependent on the optic nerve, and a very complex apparatus, consisting, in man,—1*st*, Of external protective parts; 2*d*, Of a set of muscles destined to move the organ of vision in various directions; 3*d*, Of the expansion of the nerves, and the addition of a ganglionic structure, whereby the rays of light are received, and the influence of the impressions they excite conveyed to the brain; and 4*th*, Of an optical apparatus, consisting of transparent media, which refract the rays of light upon the retina. The eyeball itself consists of an external fibrous coat, a middle or vascular coat, an internal or nervous coat, and of contents composed of refractive media. A minute description of these parts is purely anatomical. All that need be referred to here is the function,—*1st*, Of the individual parts; and *2d*, Of the entire organ as subservient to the sense of sight.

1. The external protective parts, composed of the eyebrows, the eyelids, and eyelashes, serve to shade the eye from excess of light, to diffuse over the cornea the sebaceous matter and lacrymal fluid, whereby the surface is kept ductile and moist; and lastly, to prevent the access of dust floating in the atmosphere. These different actions are for the most part involuntary, and carried on partly by the cerebro-spinal, and partly by the ganglionic system of nerves performing excito-motory, excito-secretory, and excito-nutrient functions. The watery fluid secreted by the lacrymal gland, and which is diffused over the anterior surface of the eye by the motion of the lids, keeping it moist and translucent, is conducted by two openings in the inner corner of the eye through the lacrymal duct into the nose, from whence it is discharged. 2. The eye-ball has a remarkable amount of mobility, in consequence of six muscles, four straight and two oblique, which act upon it in various ways. They are supplied by the third, fourth, and sixth pairs of motor nerves, and by a sensitive branch of the fifth pair. The object of so many nerves being distributed to them seems to be the correction or prevention of the simultaneous action which would take place in the two eyes if all their muscles were supplied by branches of the same nerve. 3. The optic nerve, on entering the eyeball, is a little compressed, but on reaching the internal surface branches out to form a membrane. On the inside of this membrane,

however, are placed several layers of ganglionic cells, and externally, a membrane (Jacob's membrane) composed of minute columns or rods, standing vertical to the retina, and composed of a structureless, transparent substance like glass. The whole retina is transparent, and it is now supposed that the rays of light pass through it backwards, and are reflected by these rods, or Jacob's membrane, forwards to the sensitive branches of the optic nerve, which conveys the influence of the impressions so excited to the brain, to produce the sense of vision. For this purpose, the rods appear to be connected with the filaments of nerve by means of connective fibres. 4. The optical apparatus consists of four lenses of different structures, densities, and curves, filling up the substance of the ball, and forming, with the strong external case, or sclerotica, a perfect achromatic camera obscura. The most anterior of these lenses is the cornea, composed of condensed epidermis resembling horn; and hence its name. The second lens, proceeding backwards, is composed of a watery fluid, or aqueous humour, principally accumulated between the cornea and the iris. The third lens is the crystalline,—one of the most remarkable bodies in nature,—composed of concentric laminæ, like those of an onion, united by serrated or notched surfaces, and increasing in density from the circumference to the centre. The fourth lens, or vitreous humour, is of gelatinous consistence, fills up the large proportion of the ball, and appears to be a watery fluid inclosed within fibrous meshes of the greatest tenuity and fineness. These horny, watery, glassy, and gelatinous lenses, united, fulfil all the conditions optically required to produce achromatism so perfectly as to set the optician's art at defiance. In addition to the lenses, the eyeball is lined by a black opaque membrane, the choroid, to absorb unnecessary rays of light, the entrance of which is further regulated by a moveable aperture in the contractile iris, called the *pupil*, which is operated upon by excito-motory influences, so as to produce its contraction or enlargement.

In regarding the entire eye as an organ of vision, there are various points which deserve consideration. Among these are,—1. The means by which the apparatus is so readily accommodated to various distances. On this subject numerous theories have been advanced, all of which answer the purpose, if the truth of certain data be granted. It has been supposed that the curvature of the cornea is changed; but this has not been demonstrated. It has been imagined that the curvature of the lens is changed; a view which has in recent times again been supported by the observations of Kramer. It has been thought that the lens is drawn forward by a contractile non-voluntary muscle—the ciliary muscle—or is pushed forwards from behind by the turgidity of the ciliary processes. Some have thought that the contractions of the iris have much to do with the focal adaptation of the eye; and others, that it is owing to the pressure on the eyeball of the external muscles which move it. The question is still undecided. 2. The natural power of adaptation is interfered with in myopia, or short-sightedness; in presbyopia, or long-sightedness; and in amblyopia, or a peculiar dimness of vision. The first is owing to too great curvature of the lenses, and is corrected by concave glasses in spectacles; the second is produced by too little curvature of the lenses, and is corrected by convex glasses in spectacles; the third is owing to altered shape or oblique position of the lens, and is corrected by the use of cylindrical glass lenses. 3. Another perversion of vision consists of what is called colour-blindness, or Daltonism. Some persons cannot distinguish colours at all, everything appearing shadowed or light, like an engraving. Others cannot see brown, gray, or neutral tints; whilst a third class confound red, blue, and yellow with green, purple, orange, and brown. Red, blue, and yellow are never confounded with each other; but red and green are most commonly so. This condition may be dependent on some fault in the nerves of vision, possibly in the retina, and more especially in the refractive rods; or it may be owing to some change in the refractive media or lenses. But the theory is not yet determined. 4. All objects refracted on the retina are inverted, and yet we see them in their natural position. To explain this fact, it has been supposed that during infancy this sense, with all the others, undergoes a slow education, and that one so corrects the aberrations of the others that gradually we learn to recognise things as we do. The case of Cheselden, who operated on a young man successfully who had been born blind, in consequence of congenital cataract, contains many facts in favour of this view. 5. The circumstance of our seeing one object, although we receive two images in the two eyes, is explained by the regular action of the muscles of the eyeball. When this is deranged, as in squinting, or from the use of narcotics, we see double. Sometimes only half or a part of an object is seen; a circumstance attributed to paralysis of a portion of the retina, or to some disorder of the brain connected with the terminations in that organ of the optic nerves. 7. The retina, at the point where the optic nerve enters it, is insensible; whereas the foramen of Sömmerring, in the direct axis of the eye, perfectly transmits the rays of light. This aperture, however, is not deficient in Jacob's membrane; a circumstance which points out the great importance of that structure as a sensitive medium. 8. An impression made on the retina remains a certain time. This is proved by looking at a dazzling light or bright colour, and observing that, on turning away the head suddenly, it continues for a longer or shorter period. 9. Some persons are subject to ocular spectra. Remarkable objects, inanimate or living, may appear before them, and have all the aspect of reality. They always depend on a state of nervous exhaustion, from ill health, mental depression, or the use of certain drugs, as alcohol, opium, or other narcotic substances.

Hearing.—It is necessary for hearing that certain oscillations in the air, water, or solid bodies should reach the expanded filaments of the auditory nerve, and that the influence of impressions so produced should be conveyed to the brain. This is accomplished through the medium of a very complicated organ or acoustic apparatus, the ear, for a description of which we must refer to works on anatomy. The most essential part of the organ is the vestibule, that exists in every class of animals in which an auditory apparatus is to be detected. There also the principal expansion of the auditory nerve takes place, and there it is brought into connection with the vibrations of sound from the exterior. In man, such is the complication of parts superadded to the vestibule or central ear,—viz., the cochlea and semicircular canals,—that the whole is denominated the *labyrinth.* It consists of chambers and canals hollowed out in the solid part of the temporal bone, containing a fluid, in which various branches of the auditory nerve are ramified, and so arranged that the slightest vibration communicated to the fluid must affect the nerve. In man, sonorous vibrations reach the labyrinth in two ways:—1*st*, Through the external ear; and 2*d*, Through the bones of the head. The ticking of a watch is heard as distinctly when placed between the teeth as when applied to the ear, and the note of a tuning-fork, when it can be no longer heard by the ear, again gives rise to sound when placed in contact with the teeth. It is by the direct vibration of the bones of the head also that we become cognisant of the sound of our own voices. It has been supposed that the cochlea is that part of the labyrinth more immediately connected with those direct vibrations; whilst the vestibule and semicircular canals is that portion of it which enables the nerve to receive vibrations from without, indirectly, through the air. These latter vibrations, however, are diminished or intensified by means of the external and middle portions of the ear. The former, or auricle, serves to collect the sounds, and convey them through the short channel, or meatus, to the membrane or drum of the ear, which closes it internally. In this passage a number of ceruminous glands pour out a waxy secretion of a bitter taste, which, with the hairs that grow from it, serve as a very sufficient protection from foreign bodies, and especially insects. The *membrana tympani*, or drum of the ear, is connected with one end of a chain of small bones (called the *malleus*, *incus*, and *stapes*), which pass across the middle ear, or cavity of the tympanum; the other being attached to a membrane which closes the oval opening into the cavity of the vestibule. These moveable bones render the membranes tense or lax according to the intensity of the sonorous vibrations impinged upon them. This is accomplished through the agency of minute muscles which contract according to the influences transmitted by a series of excito-motory nerves. Hence this part of the apparatus is admirably adapted to carry the nicest vibrations in such a manner as will enable them best to conduce to the production of impressions on the auditory nerve. The cavity of the tympanum or middle ear is filled with air, which passes through the Eustachian tube. This not only permits the free vibration of the chain of ossicles, but further serves to keep the air of a uniform temperature; a circumstance of the greatest importance to the continuance of good hearing.

There is much similarity between the laws which govern the reception and reflexion of sonorous vibrations and of rays of light; and, looking at the means necessary to effect this, there is a close analogy between the ear and the eye as organs of hearing and vision. The intensity of light and of sound are both regulated by muscular parts, independent of the will, operating through a ganglion and excito-motory nerves; the ciliary resembles the cochlear muscle, and the reflecting-rods of Jacob's membrane have their analogue in certain vibratory rods attached to the acoustic nerve where it is expanded on the *lamina spiralis* of the cochlea. But not to carry the comparison further, it may be noticed, that impressions made on the auditory nerve, like those on the retina, remain a certain time, as is shown not only by interrupted vibrations producing continuous musical tones, but by the experiments of Savart, who found that the removal of one or more teeth from toothed wheels when in motion occasioned no appreciable difference of sound.

VOICE AND SPEECH.

Voice is a function of the larynx, while speech is performed by the tongue, lips, and cheeks, in conjunction with the larynx. An anatomical description of this organ is here unnecessary. All that need be said is, that it is composed of a tube made up of cartilages, which are connected together by ligaments, and moved upon one another by muscles. In the interior of the tube is a narrow chink in the shape of the letter V, having the point forwards, formed by two folds of membrane called the *vocal cords*, which, thrown into vibration by the air rushing from the lungs, give rise to sound. Different degrees of tensity are given to these cords; and the chink, or *rima*, of the glottis is widened or narrowed by the various muscles of the larynx, and by the position of the cartilages; points that can only be understood by a careful study of the organ, which, in construction, resembles the mouthpiece of a clarionet or hautboy.

Voice.—Nearly all air-breathing animals possess a voice; in man and a few birds only can it be so modified as to be capable of producing articulation. The vocal cords are caused to vibrate by the currents of air coming from below, and at once lose this power by destruction of the laryngeal nerves, which, by paralysing the muscles that regulate their necessary tensity, prevents their vibration and the production of sound. These vocal cords, therefore, are the essential parts of the organ of voice. Their tensity is varied sometimes by muscular action, and sometimes by the column of air. Thus, to produce low notes they are relaxed, and even wrinkled when at rest, but obtain the necessary degree of stretching by the pressure of the column of air. High notes, on the other hand, are caused by producing great tensity of the cords, and narrowing of the glottis; and intermediate notes, by intermediate degrees of tensity, and narrowing. The quality as well as the compass of the voice varies in different persons. In the male the deepest is the bass, the highest the tenor, and the intermediate the baritone. The corresponding tones in the female are the contralto, the soprano, and the mezzo-soprano. In men, owing to the prominence of the thyroid cartilage, the vocal cords are longer than in the female, as 3 to 2; and his voice in consequence is deeper, and in the musical scale an octave lower. Boys have treble voices, like women; but as manhood approaches, the thyroid cartilage undergoes a change in its form, and while doing so the voice is cracked or broken. Afterwards it becomes manly and deep; so that the highest soprano of a boy may be converted into the deepest bass of the man. Male voices also possess two series of notes,—chest or true notes, and false or falsetto notes. How the latter are produced is unknown. The strength of the voice does not so much depend upon the current of air, as upon the strength and accuracy of the muscular movements regulating the vocal cords. Hence why practice, which gives accuracy and tone to the muscles, is of such importance in the schools of singing.

Speech.—The voice, so modified by the additional action of the tongue, cheeks, and lips, as to signify objects, actions, and the properties of things, constitutes language. Languages vary greatly as to the sounds which enter into them, and hence the difficulty persons who have been educated in one, experience in learning others. Words, however, may be produced by the mouth and fauces alone, without the voice. This is whispering. Hence there may be speech without voice, as there is voice without speech. Vocal language, however, can only be accomplished by the combined use of the laryngeal and oral apparatuses. Articulate sounds are divided into vowels and consonants. Vowels are formed in the larynx, whilst consonants are produced in the air-passages above it. Many of these last, however, cannot be uttered unless the elements of a vowel are pronounced with them consonantly; hence their name. Thus *g* and *k* are formed of the vowels *e* and *a*, modified by the oral aperture. It is by different degrees in the opening and contraction of the mouth and oral canal that most continuous sounds are formed; others are sudden and momentary, cannot be sustained, and are called explosive sounds, such as *b*, *p*, *d*, and *g*. Hence they are difficult to pronounce well in singing; and this is why the Italian language, in which they are seldom heard, is so much better adapted to songs than English or German. When the laryngeal and oral parts of the organ of speech cannot be combined, some letters, especially the explosive ones, as *t* and *p*, are not consonant with the vowel; and stammering is the result. It is to be corrected by a careful study of the mode of pronouncing the various consonants, with constant practice—avoiding hurry and nervous agitation, which render all muscular action uncertain. Ventriloquism is speaking without giving external evidence of utterance, and keeping the oral aperture immoveable while the attention of the audience is directed as much as possible to the thing or place from which the voice is supposed to come.

SLEEP—DREAMS—SOMNAMBULISM—MONO-IDEISM.

Sleep is that temporary suspension of the cerebral functions which in animals alternates with their exercise for a certain time, which suspension, however, is capable of interruption on the application of stimuli to the sensory nerves. Unless this last condition could be carried out, the individual would labour under coma, syncope, or asphyxia,—states more or less allied to sleep. All action in the living economy produces waste of tissue; and hence the necessity of rest in order that substance may be added. The cerebral functions, especially, are governed by this law, and we are obliged to submit to their suspension for a certain period, which is natural sleep. On awakening, we feel refreshed; greater strength is imparted to the muscles, higher sensibility to the nerves, and greater power to the mind. Sleep is more or less profound according as the body is more or less fatigued, and according to the constitution of the individual; as in some persons it is naturally light, whilst in others it assumes a soporose character. Habit and temperament also exert a strong influence over sleep, some persons falling into or arousing from it at particular hours, independent of all other circumstances. Its invasion may be sudden or gradual. As a general rule the senses and reasoning faculties sleep first, whilst imagination and the lighter ones remain longer awake. We may also awake suddenly; but there is usually an intermediate condition between sleep and waking. It is in these intermediate conditions that the sleep is lightest, and that persons can be aroused with the greatest facility. The amount of sleep required by man varies according to age, temperament, habit, and previous fatigue. In infancy and extreme old age life is almost a continuous sleep. In adults there is no rule, some persons requiring more and some less. The average period spent by mankind in sleep is eight hours in the twenty-four, being one-third of human life.

Dreams.—Not unfrequently while some mental faculties are suspended others are still active, and are busy with numerous ideas, which succeed each other with more or less regularity. This is dreaming. There is an absence of consciousness regarding external things, and a want of control in regulating the current of thought; so that the principle of suggestion—that is, one thought calling up another in a certain sequence—has unlimited governance of the mind. In some rare cases the dreaming thoughts are very consistent and vivid, but generally speaking they are more or less confused or incongruous. Not unfrequently, when seemingly in danger, we are governed by an intense desire to escape from it, while we possess an agonizing consciousness that we have not the slightest power to do so. This is *incubus*, or nightmare. Another curious circumstance is the rapidity with which, when dreaming, trains of thought pass through the mind, the events of years being apparently compressed into moments. The most mentally agitating dreams need not occasion the slightest change of position or muscular movement, although sometimes they produce restlessness, various gestures, or emotional indications. But when the ideas of a dream govern the motions and conversation of an individual, while the memory and other faculties of the mind are still so suspended that on awakening he is quite unaware of what has occurred, the condition is called *somnambulism*.

Somnambulism.—The peculiarity of this state consists in the mind being wholly occupied with one idea or train of thought, to the exclusion of all other considerations. Thus there may be complete insensibility to bodily pain, to loud sounds, flashes of light, or other ordinary stimuli; although whatever is spoken or done in harmony with the subject thought of is heard and appreciated, often with unusual acuteness. We can frequently change the current of the ideas by audibly suggesting others, when all the feelings and emotions in connexion with the new subject are called into action, to the exclusion of those which previously existed. Thus if the attention be strongly fixed on a distant object, impressions made on the skin will not induce sensation; but if the attention be directed to the skin, its sensibility often becomes wonderfully excited, and pain is experienced from the contact of bodies that, under ordinary circumstances, would scarcely be felt. The same rule applies 'to all the other senses. In the same manner the reasoning power is often increased on a particular point, and a variety of things performed, or movements gone through, that the individual otherwise could never have accomplished. Some men perform all the acts which at the time are suggested to them, or describe the various scenes which in imagination are placed before them. In this way a somnambulist may be made not only to think and converse on any subject, but to go through any kind of action, however ridiculous or even fatiguing. He will place himself under every variety of condition presented to his mind, and perform the appropriate motions, as well as give utterance to the ideas which such conditions would naturally give rise to. Thus he may be made to hunt, swim, fight, appear intoxicated, visit distant cities or lands, &c. None of these acts and ideas are remembered in the ordinary waking condition, although when again thrown into a similar state, they may be taken up and continued. Such a person may be said to have two kinds of memory,—one when awake, and one when dreaming; or, as it has been called by some, a *double consciousness.* Somnambulism may come on involuntarily, at regular or irregular periods, or it may be excited artificially. In either case it may be accompanied by various nervous phenomena, denominated *catalepsy, trance, ecstacy,* and so on.

Mono-ideism.—Dreaming and the phenomena of somnambulism may be excited in some persons artificially, when the acts of the mind, sensation, and motion may be completely governed by means of suggestive ideas, even although the individual be conscious. This state has been called *mono-ideism.* (Braid.) The mode of effecting this is to cause a certain number of persons to fix their attention on a small object, as a coin, or submit to have monotonous passes made with the hands before their face. On an average, at least one person in twenty so treated feels in a shorter or longer time, first a mistiness of vision or stiffness in the eyelids, and occasionally deep-drawn sighs, hurried respiration, and signs of general excitement are visible. If now such persons are respectively told in a confident manner that they cannot open their eyes, it will be found that they cannot do so, especially if their attention be more strongly directed to the eyelids by touching or by pointing to them. But on receiving permission, or on being commanded to open them, this is done at once. Such persons may now, as in certain cases of somnambulism, have every kind of motion, sensation, or mental act produced, governed, or arrested, according to the endless train of suggestive ideas that may be communicated to the individual. Many of the lower animals also appear to be susceptible of being impressed by what strongly arrests their attention, in such a way that they are rendered incapable of voluntary motion, or irresistibly impelled towards the object. Hence the long glittering bodies of serpents, or the glaring eyes of other animals, *fascinate* birds and small quadrupeds, and render them an easy prey to their enemies. Similar effects are produced in individuals who look from heights and precipices, and experience an uncontrollable desire to leap down, although it be to certain destruction.

Like phenomena have occurred in all ages, produced in certain persons by predominant ideas, and variously modified according to the education, politics, or religion of the period. Thus the effects produced on many votaries during their initiation into the ancient mysteries; the ecstacies of the Pythian and other priestesses; the influence of religious enthusiasm; the dancing epidemics of St Vitus or of Tarantism in the middle ages; the hallucinations of the Convulsionaires at the tomb of St Medard, in Paris, &c. &c., are of the same character. Numerous perversions of the nervous functions, identical in their nature with those described, consisting of sensory illusions, muscular convulsions or rigidity, and peculiar trains of thought influencing acts and conversation, may be found in the histories of witchcraft or demonology, in the legends of the saints, the journal of Mr Wesley, and in the accounts given by travellers of the religious camp-meetings in the woods of America. They are perhaps more common now than formerly, and excite even more astonishment among the ignorant; the only difference being, that the same phenomena, which in a dark age were attributed to divination or incantation, now assume the garb of science, and are ascribed to magnetism or electricity.

It is unnecessary to enter into any lengthened argument to refute the numerous hypotheses which ascribe these effects to external influences. There is no series of well-ascertained facts capable of supporting such a doctrine; whereas it would be easy to prove that all the phenomena really occasioned depend on suggestive ideas communicated to the person affected. But while these theories scarcely merit attention, the facts themselves are highly important, and demand the careful consideration of the physiologist and medical practitioner. The effect of mind on the body has from the earliest periods been seized upon by individuals as a ground for veneration or astonishment. In ancient times the heathen priests were the physicians, and the temples were converted into so many dispensaries, at which the sick applied for relief. In Catholic countries, during the middle ages, the offices of priest and physician were frequently united in one person; so that the powerful effects of certain shrines, and the benefits of pilgrimages in cases not admitting of simple cure, met with every encouragement. From what has preceded, it must be allowed that, so far from its being improbable that real cures were so effected, all that we know of the effects of confident promises on the one hand, and belief on the other, render it very likely that many such occurred. The legends of the saints, the history of witchcraft, the journal of Mr Wesley, the accounts of celebrated pilgrimages, and of the virtues of particular shrines, and the writings of religious enthusiasts generally, abound in wonderful cures. Charms, amulets, and relics are stated to have at once banished all kinds of agony, and removed numerous nervous diseases. Many of these are certainly incredible, whilst others are perfectly conceivable. The benefits of the royal touch are confirmed by the observations of Richard Wiseman, and the cures performed by Greatrakes are warranted by Robert Boyle. In all these cases, there can be little doubt that any benefit which did occur may be attributed to a strong belief, on the part of the patient, in the efficacy of the means employed. There can be little doubt that the facts recently ascertained in connection with this subject open up a new field for investigation, not only in physiology and practical medicine, but in what relates to evidence as it is now received in courts of law.

As regards the nature of this condition, it seems analogous to that of sleep or dreaming, in which certain faculties of the mind are active, and may be even stimulated into excessive action, whilst others are suspended. All the phenomena produced are strictly analogous to what medical men are acquainted with in various morbid states; and it must now be considered as well established, that in certain conditions of the nervous system they may be induced at will. This conclusion, however, is something new, for it has but recently been received in physiology or pathology, that a condition of the cerebral functions may be occasioned in apparently healthy persons in which suggestive ideas are capable of producing those phenomena we have described, and which render them, for the time, as irresponsible as monomaniacs. Yet such is really the fact, and once admitted into physiology, must have an important influence on the theory and practice of medicine. Such a condition may probably be accounted for physiologically in the following manner:—

We have previously seen that the cerebral lobes contain white fibres, which run in three directions:—1*st*, Those which pass from below upwards, and connect the hemispherical ganglion with the spinal cord; 2*d*, Those which pass transversely, forming the commissures, and which unite the two hemispheres; and 3*d*, Those which run from before backwards, uniting the anterior with the posterior lobes on each side. It has also been stated that these fibres are probably subservient to that combination of the mental faculties which characterizes thought. Now all metaphysicians and physiologists are agreed that the mind is composed of various faculties, and that different portions of the nervous mass are necessary for their manifestation. True, it is by no means determined what or how many faculties mind should be divided into; still less is it known which parts of the brain are necessary for the manifestation of each. But let the first proposition be granted, then there is no difficulty in supposing that one or more of these may be paralysed or suspended, whilst others are entire, any more than there is in knowing that sensation may be lost whilst motion remains intact, although the nerve fibres of both run side by side. It may be presumed, then, that certain mental faculties are, as the result of exhausted attention, temporarily paralysed or suspended, whilst others are rendered active in consequence of being stimulated by suggestive ideas; that the psychical stimuli of the former make no impressions on the cerebral conducting fibres, whilst those of the latter are increased in intensity; that the proper balance of the mind is thereby disturbed, and thus the individual for the time being acts and talks as if the predominant idea was a reality. The condition is analogous so far with ordinary somnambulism, certain forms of hypochondriasis, and monomania, but admits of infinite changes, from the nature of the idea suggested.

According to this theory, therefore, we suppose that a psychical stimulus is generated, which, uncontrolled by the other mental operations acting under ordinary circumstances, induces impressions on the peripheral extremities of the cerebral fibres, the influence of which only is conveyed outwards to the muscles moved. In the same manner, the remembrance of sensations can always be called up by the mind ; but under ordinary circumstances we know they are *only* remembrances, from the exercise of judgment, comparison, and other mental faculties ; but these being exhausted, in the condition under consideration, while the suggested idea is predominant, leave the individual a believer in its reality.

In this manner we attribute to the faculties of the mind a certain power of correcting the fallacies which each is liable to fall into, in the same way that the illusions of one sense are capable of being detected by the healthy use of the other senses. We further believe that the apparatus necessary for the former operations consists of the nerve-fibres which unite different parts of the hemispherical ganglion, whilst that necessary for the latter are the nerve-fibres connecting together the organs of sense and the ganglia at the base of the encephalon. A healthy and sound mind is characterized by the proper balance of all the mental faculties, in the same manner that a healthy body is dependent on the proper action of all the nerves. There are mental and sensorial illusions, one caused by predominant ideas, and corrected by proper reasoning ; the other caused by perversion of one sense, and corrected by the right application of the others. Both these conditions are intimately united, and operate on each other, inasmuch as voluntary and emotional movements and sensation are mental operations.

This theory, if further elaborated, appears to be consistent with all known facts, and capable of explaining them on physiological principles.

FUNCTION OF REPRODUCTION.

The process whereby the countless variety of organisms which constitute the vegetable and animal worlds is perpetuated on the surface of the globe has from the earliest periods attracted the attention of physiologists, naturalists, and philosophers. In recent times, the excellence of the achromatic microscope has enabled us to penetrate much further into the mysteries involved in it, and the whole subject is now one of vast extent. We shall speak of this function as consisting of three stages:—1*st*, The production and discharge of germs; 2*d*, Of the fecundation of such germs; 3*d*, The changes which follow fecundation.

THE PRODUCTION AND DISCHARGE OF GERMS.

We have seen that at the earliest period of development in all organized beings, without exception, there is formed a molecular blastema which originates a nucleated cell. Up to that point where sexes are manifest, the process of reproduction is identically the same with that of cell growth. The peculiarity of the function of generation in the higher organisms consists in the superaddition to this process of a particular act, whereby the further development of germ-cells is occasioned. There is a special apparatus in animals and in plants—the ovary,—the function of which is to mature a germ, that from the time of its first formation is capable of becoming the rudiment or embryo of a new being, and which is often separated from its parent in a form altogether dissimilar to that which it is ultimately to assume. This sometimes takes place as a spore, at others as an egg; and hence the terms *sporuliferous* and *oviparous*, as distinguished from *viparous* reproduction. The more heterogeneous a structure becomes,—that is, the more difference is manifested in the structure and properties of its separate parts,—the less title has any one to be regarded as a separate individual, since it cannot maintain an independent existence, nor reproduce the entire structure. When an organism merely consists in a multiplication of similar parts, these parts may separate, and constitute independent existences, as in the Algæ among plants, and in the Polypes and Radiata among animals. This has been called *fissiparous* generation—a mode of reproduction that can never take place in the more highly organized beings. This manner of propagation is identical with that of multiplication by cells alone, with this difference, that at one period groups of cells are aggregated and united together, and afterwards separate.

Germ-cells are constantly forming and ripening in the ovaries of plants and animals, and are separated from them at particular times. In the separation of these oviparous cells, indeed, a tendency to periodicity is manifested. Thus, plants flower at certain seasons,—some in spring, others in summer, and a third class in autumn or winter,—with great regularity. Throughout the whole range of animals the same thing is observable. They all present a breeding period, at which time only ova are fully developed, and capable of being fecundated. The reproductive organs of plants and animals at this time become elevated in temperature. Among plants, this is most appreciable in the Arum tribe, where flowers are collected in great numbers within cases which act as non-conductors. On one occasion, Brogniart observed that in the *Colocasia odora* the temperature had been demonstrated to be 8° above that of the surrounding air. This was increased in the following day to 18°, and during the emission of pollen on the three succeeding days to 20°, after which it began to diminish with the fading of the flower. In animals, the same elevation of temperature has caused agriculturists to denominate this season as the period of heat. It originates in them from excessive congestion in the capillaries of the part, causing great local and more or less general disturbance of the system, the result of an augmented nutrition in the ovaries necessary for the development of the ova. This congestion causes rupture of the vessels and discharge of blood, which in the human female, and in a few of the monkey tribes, causes an external flow, known as the *menstrual fluid*, while the process in them has received the name of *menstruation.* The essential part of the act, however, is not the discharge of a fluid externally, but the formation, ripening, and separation of ova from the ovaries. Multitudes of seeds and of ova are formed in this manner, at regular periods, in plants and animals, which prove abortive, and the history of which is identical with the formation, ripening, and disintegration of simple nucleated cells, which have no power of reproduction.

The manner in which ova are formed in the ovary has been well studied by Martin Barry, who informs us that molecules and granules are deposited in groups among the fibrous stroma of the organ. Around a large granule smaller ones are aggregated, and become surrounded by a membrane—the *ovisac,*—so as to form a nucleated cell containing granular matter. This granular matter now separates into two portions. The inner forms a membrane that immediately surrounds the yolk, and from its transparent appearance has been called the *zona pellucida.* The outer divides into two layers, one of which, covering the *zona pellucida*, he called the *tunica granulosa;* and the other, which lines the ovisac, the *membrana granulosa.* These two membranes are united together by four bands,—the *retinacula,*—having transparent fluid between them.

The whole structure now forms a vesicle, which, from its first describer, De Graaf, has received the name of *Graafian vesicle,* and consists of an outer fibrous and vascular membrane; another inner one,—the ovisac of Barry,—having suspended from it, by the *retinacula,* the ovum, composed of *zona pellucida,* yolk, and germinal vesicle. Graafian vesicles may frequently be seen before puberty in the ovary, but after that period they increase in number, and may be observed in all stages of development scattered through the substance of the organ, those most advanced being near the surface. Towards the end of each menstrual period, such as are ripe burst, from the quantity of sanguinolent serum or blood which is poured into them from the external vascular membrane, and the ovum escapes from the surface into the fimbriated extremity of the Fallopian tube, which closes round the ovary, in order to receive it, and through which it is conveyed to the uterus.

The cavity thus left in the ovary is most frequently filled with coagulated blood, the result of hæmorrhage from the vascular or external layer of the Graafian vesicle, which participates in the congestion of the menstrual period. This coagulum of blood becomes gradually absorbed, in the course of which it changes its colour, and assumes a yellow and puckered appearance. In this state it has been called *corpus luteum,* and it has been supposed to present such peculiar appearances when fecundation has occurred as to warrant medical men in asserting that pregnancy had taken place—a grave error, which modern science has completely exploded. These appearances are described as being,—1*st,* An irregular form in the false, but a regular one in the true *corpus luteum ;* 2*d,* An absence of a central cavity lined by a membrane in the false, whilst in the true there are both; 3*d,* Absence of concentric radii in the false, while in the true they are present; 4*th,* The false may be present in both ovaries, while the true only exist in one. All these signs have been shown to be in no way distinctive by numerous recent observations. Thus, in women who have never had children, there have been found *corpora lutea* exactly resembling those supposed to follow pregnancy. In the lower animals, also, four or five *corpora lutea* have been found in the ovaries, resembling each other, although one fœtus only was found in the uterus. It must be manifest that these ideas were the result of the notion that fecundation took place in the ovary, which assuredly it never does. Whether a *corpus luteum* during pregnancy disappears less rapidly than in the unimpregnated state is not known, but such is the only possible difference which can exist in the two states. That it is possible for any physiologist or pathologist to pronounce with certainty between the bodies which do or do not coincide with pregnancy, has been demonstrated in the negative by several remarkable cases which have been raised in the courts of law.

The capability for procreation marks a peculiar period of life, which has been called puberty, on account of the development the pubes then undergoes. In woman, this generally occurs between the thirteenth and sixteenth year, but is earlier in warm climates, and later in cold ones. It has also been observed to be earlier in manufacturing towns than in thinly-peopled districts. Mental and bodily habits exercise an influence; girls accustomed to luxury and indulgence undergoing this change earlier than those reared in hardihood and self-denial. At this time those general and local changes occur which distinguish the adult woman: the mammary glands enlarge; a deposition of fat takes place in the cellular tissue of the skin, which gives to the female form its roundness and fulness; and the menstrual fluid, the most unequivocal sign of puberty, commences to flow. In man, puberty is marked by the low and rough voice—from the size of the larynx and elongation of the vocal cords; by the growth of hair on the chin, upper lips, and cheeks, as well as over the body and limbs; the greater physical power and activity, as compared with the female; the capability of enduring more fatigue; and a larger amount of courage and daring.

FECUNDATION OF GERMS.

The germ-cells, prepared and formed in the ovaries, are discharged from those organs at each menstrual period, and would be excreted from the economy without being further developed, unless they encountered vibratile particles formed in another organ. In phanerogamous plants, the pollen tube enters that of the pistil, and the pollen itself is conveyed to the ovule at its base. The contact of the pulverulent pollen with this ovule fecundates the latter. Of the nature of the stimulus so imparted we know nothing; but the fact is well established in science, that no ovule can furnish productive seeds unless the pollen has had access to it. In all animals in which ova are formed the same thing takes place. Two sets of organs analogous to those in plants are found. In some creatures, as in certain Mollusca, these are also associated in one individual; but in all the vertebrate tribes they exist in different animals, male and female. The former is furnished with organs called the testes, which secrete the spermatic or seminal fluid. This contains minute bodies, possessed of independent motion, which they retain for several days after they have been excreted. In them the fecundating power resides, for it is only when these come in contact with the ova discharged from the ovary of the female that the latter are ever developed into distinct living beings. From this moment that series of changes commences in the ovum whereby an embryo is formed. For this purpose, however, various circumstances are necessary, especially a fitting locality, proper temperature, moisture, &c. Seeds which have been impregnated retain a dormant degree of vitality for many years, and when at length placed in these favourable circumstances, they develop themselves. Generally speaking, instinct guides the lower tribes of animals to deposit their eggs in appropriate localities; and the extraordinary variety of such positions selected by insects, fishes, and reptiles, has furnished a curious subject of observation for the naturalist. In birds, the fecundated ova are hatched by the mother, who elevates them to a proper temperature by the heat of her own body. In mammiferous animals, the young are not born as ova; an organ—the uterus—is provided for their reception, where they grow and become developed; and when at length they are capable of supporting an independent existence, they are excreted or parted from the body of the parent by the process of parturition.

The form of the vibratile seminal particle varies in different animals. In mammals generally, it has a round or oval extremity, a so-called head, and a filiform appendage called a tail, and varies in length from the 100th to the 500th of an inch in length. In birds, the thick extremity is more tapering, and the whole is of a spiral form. In certain reptiles and fishes, the filament is much longer, and thickest in the middle, tapering at both extremities, having occasionally a delicate continuation wound spirally round the thicker portion. In some insects and crustacea, they present curious irregular forms, without a filament, and are immoveable. In the vast majority of cases, however, they possess active contractile movements. In mammals especially, when watching these under the microscope, it is difficult to divest oneself of the idea that they are animalcules, as they progress through the fluid with the heads forward, propelled by continued vibratile lashings of the tail. The notion put forth by some observers, that they possess internal organs, we have never, after careful research, been able to confirm; and the circumstance that similar structures, with like movements, exist in the reproductive organs of many plants, negatives the idea of their being distinct animalcules.

The mode of fecundation varies in different animals. In some molluscous tribes male and female organs are united in one animal. It is an hermaphrodite, like many plants, and is self-impregnated. In fishes, the female sheds its spawn, and the male, swimming over it, sprinkles the spermatic fluid on the ova, and may be observed at the breeding season to follow her for that purpose. In the higher animals, union of the sexes takes place for the same end. In reptiles, especially in the frog and toad, the male sits on the back of the female, and sheds the semen over the ova immediately after they have left the cloaca. In birds and mammals, it is necessary that the spermatic fluid be deposited in the body of the female by the intromission of the male organ. From the circumstance that fecundation may take place in fishes and reptiles, as in plants, by simply sprinkling the male element over the female ova, has originated the modern practice of artificial impregnation. In the same way that horticulturists can multiply varieties, and even fertilize plants with pollen received from a distance; so, by sprinkling the fluid from the milts of male fishes over the innumerable ova which may be squeezed from the roe of the female, they may be fecundated, preserved, and reared in artificial ponds. At this moment, many of the rivers and lakes of France and Scotland are being stored with large accessions of valuable fish so raised, in order to increase the amount of food for the people.

For a long time it was supposed that the mere contact of the vibratile spermatozoids with the ova was all that was sufficient to produce fecundation; but it was first shown by Martin Barry, and has been subsequently confirmed by many other physiologists, that the spermatozoid actually finds its way into the ovum by a minute aperture, and that the male and female elements ultimately blend or melt into one another. This fact may now be considered well established, and serves to explain many circumstances long known as to the resemblances which exist in feature and in qualities, mental and bodily, between parents and their offspring. Thus, it has long been a matter of popular observation, that the child, in all that relates to the outward form, the gait and manners, takes after the father; while as regards the size, internal qualities, and dispositions, the mother predominates. Not, however, that the male is wholly without influence on the internal organs and vital functions, or the female wholly without influence on the external organs and locomotive powers of their offspring. The law is only general, although it holds very extensively among cattle, as shown by Mr Orton and Dr A. Harvey. Such facts seem in their turn to be accounted for by the circumstance, that the spermatozoid enters and melts down in the external parts of the yolk of the egg,—that is, in connection with those layers of the germinal membrane which, as we shall subsequently see, form the nervous system and muscles; whereas the glands and internal organs are formed from the mucous layer, which is that part of the membrane furthest removed from the action of the male element.

CHANGES IN THE OVUM WHICH FOLLOW FECUNDATION.

We have seen that ova are formed and discharged from the ovary at regular intervals by the adult female, but that it is only when the spermatozoid enters them that fecundation is produced. At that period the ovum presents the characters of a nucleated cell, — the *zona pellucida* being the cell-wall; the germinal vesicle being the nucleus; while the fluid between them is opaque and granular, and called the *vitellus*, or yolk. (See figs. 1 and 2, p. 166.) The size and relative amount of these three parts of each ovum vary in different animals, but they are present in all. There is also generally observed at one part of the germinal vesicle a collection of granules, called the *germinal spot*. (See fig. 2, *a*.) If fecundation does not take place, the ovum degenerates, breaks down, and is ultimately excreted in the mucous discharge from the external passages. But if it encounter the spermatozoids, and one penetrates it, then those changes commence which terminate in the formation of an embryo. These changes have now been followed in numerous animals, and the principal efforts of zoologists are at present directed to the elucidation of the transformations which take place in living beings; so that the whole subject is not only very extensive, but is constantly acquiring new facts. The study of human embryology is incomplete, for, although an ovum has been twice discovered after death in the Fallopian tube of woman, it has never been seen at that period when it enters the uterus. In the dog, rabbit, sheep, and other mammals, however, the various transformations have been very carefully described; and, as it is certain that the same essential mode of development occurs in them as in man, the changes observed in the dog will be selected as a type of what takes place in the impregnated ovum of the higher animals.

When the ovum leaves the Graafian vesicle, there is adherent to it externally a greater or less number of the cells which form the granular membrane. On removing these artificially, the ovum presents the appearance represented in fig. 1, when magnified fifty diameters linear. It is composed of a dark, opaque yolk, surrounded by the *zona pellucida*, or vitelline membrane. On cracking this ovum between two glasses, or on tearing it with a needle, the granular yolk flows out, and the germinal vesicle escapes, as in fig. 2, *a*. If such an ovum encounter spermatozoids, the changes subsequently represented take place. One enters the ovum, when both it and the germinal vesicle are dissolved in the yolk,—a circumstance to which the whole structure is indebted for its continuance and for its power of, as well as direction in, development. We next observe that the granular yolk begins to separate into two parts, a process which is accomplished by the spontaneous

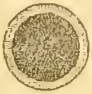


Fig. 1.

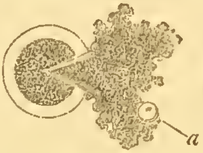
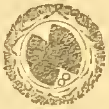


Fig. 2.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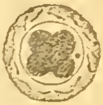


Fig. 4.

Explanation of the Figures.

The mode of development of the embryo is so difficult to understand, that it has been thought right to illustrate this part of the subject copiously by woodcuts, which will serve to indicate better than mere description can do how the various parts and organs successively come into view. They are copied from the accurate plates of Bischoff illustrative of the embryonal development of the dog, but diminished one-half.

Fig. 1.—An Ovum from the bitch freed from the granular membrane, showing the dark internal yolk, and clear external *zona pellucida*. (*Magnified* 50 *diameters.*)

Fig. 2.—The same Ovum lacerated with a needle. The yolk has flowed out, showing the germinal vesicle *a*, with its germinal spot. (50 *diam.*)

aggregation of the molecules of which it is composed into two masses instead of one (fig. 3). Each of these two subdivide, producing four (fig. 4); each of these into other two (fig. 5); and so on, until at length the whole is reduced into a mass of molecular corpuscles (fig. 7), having a clear space or nucleus in their centres, and subsequently distinct cell-walls (fig. 8). These next arrange themselves in a layer externally, immediately lining the *zona pellucida* so as to form a membrane, which is called the *germinal membrane* (fig. 9). At one part of this it will be observed that the cells and their granular contents are thicker, forming the *germinal area*, where the embryo first appears. The ovum has now entered the uterus, and its appearance at

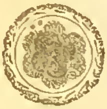
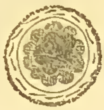


Fig. 5.



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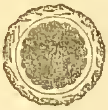

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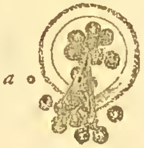

Fig. 8.

Fig. 3.—The Ovum has encountered spermatozoids, which are seen adherent externally to the *zona pellucida.* Fecundation has taken place; the spermatozoid, which has penetrated the transparent zone, together with the germinal vesicle, have been dissolved in the yolk, which is divided into two masses. (50 *diam.*)

Fig. 4.—The Yolk divided into four masses. (50 *diam.*)

Figs. 5 *and* 6.—The process of division in the yolk further illustrated. (50 *diam.*)

Fig. 7.—The Yolk now reduced by division to a large number of molecular cells. (50 *diam.*)

Fig. 8.—The Molecular Cells rendered visible by laceration of the Ovum. They contain a clear space in their centres. (50 *diam.*)

Fig. 9.—An Ovum further developed after it has been placed in water for a short time. In consequence of endosmose, the this period, magnified ten times, is represented in fig. 10. By cutting or tearing out the portion of the germinal

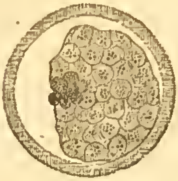
Fig. 9.

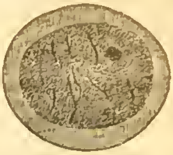
Fig. 10.

membrane which contains the germinal area, and magnifying it, the subsequent changes it undergoes can be well studied, as in the following figures.

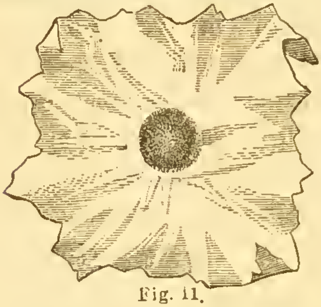
Fig. 11.

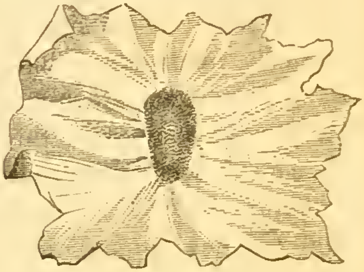
Fig. 12.

The germinal area now enlarges; at first round (fig. 11), it

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internal membrane is separated from the *zona pellucida*, and is seen to be formed by the cells which have coalesced. This is the germinal membrane, with the germinal area composed of an extra layer of cells. (50 *diam.*)

Fig. 10.—An Ovum, much larger, taken from the uterus, moistened with water. The germinal membrane is somewhat separated from the *zona pellucida*, and thrown into folds. (10 *diam.*)

Fig. 11.—Portion of the Germinal Membrane surrounding the germinal area, cut out from a further developed ovum. A clear space in the area, called *area pellucida*, is apparent. (10 *diam.*)

Fig. 12.—A similar piece from a somewhat older ovum. The germinal area has become oval. (10 *diam.*)

becomes oval (fig.12), and then appears in it a clear space, the *area pellucida.* At the same time, the germinal membrane becomes thicker, and is now easily divisible into two layers,—an upper or outer, called the *serous* or *animal*, and an under or internal, called the *mucous* or *vegetative layer.* The future changes in the embryo may be observed by watching the behaviour of these two layers, and of another that afterwards forms between them in the germinal area. In the centre of the enlarged germinal area there now forms a groove or channel, the *primitive groove*, by the elevation on each side of the germinal membrane (fig. 13). This enlarges anteriorly, and tapers to a point posteriorly (fig. 14), and ultimately becomes closed by its sides, or *laminæ dorsales*, passing over it and uniting, thus forming the foundation of the cerebro-spinal cavity, and inclosing the *chorda*

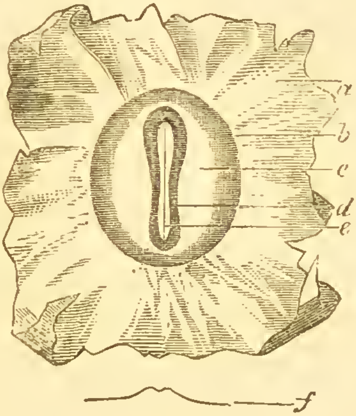

Fig. 13.

Fig. 13.—The Germinal Area is now greatly enlarged in the germinal membrane. *a.* Germinal Membrane—*b.* Limit of Vascular Area—*c. Area Pellucida*—*d. Laminæ Dorsales*—*e.* Primitive Groove.—*f.* Profile of Germinal Area. (10 *diam.*)

dorsalis, or embryo brain and spinal cord (figs. 16 and 18). A linear mass of square-shaped cells forms on each side, which is the commencing vertebral column (figs. 14 and 16).

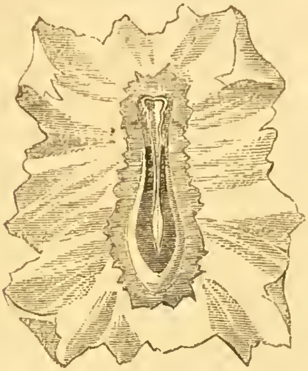

Fig. 14.

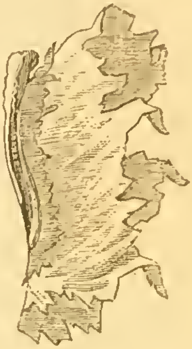

Fig. 15.

The embryo is now raised prominently upwards above the serous layer (fig. 15), and between it and the mucous layer

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Fig. 14.—Portion of Germinal Membrane, with the Embryo, from an ovum twenty-four hours older than fig. 13. The primitive groove is not yet closed, but is much stronger, especially above. Here three swellings are observable, which are the three primitive brain-cells. At the inferior end, the groove is of a lancet shape (*sinus rhomboidalis*). In the centre of the groove is a thin streak, the commencement of the *chorda dorsalis.* Six square cells are formed on each side, the commencement of the vertebral column. The germinal membrane is now composed distinctly of two layers, the upper of which (the *serous* or *animal layer*) is cut close round the embryo, showing more distinctly the lower (the *mucous* or *vegetative layer*). (10 *diam.*)

Fig. 15.—The same Embryo, seen sideways, whereby the elevation of the dorsal laminæ, and the groove between them, are better seen. The head is already distinctly elevated above the germinal membrane. (10 *diam.*)

another mass of cells is formed which constitutes the third or *vascular layer.* Here blood-vessels are developed as a plexus (figs. 16 and 17), which unites itself with the em-

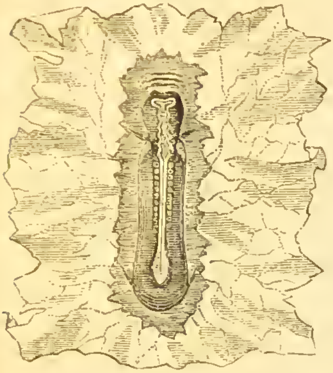


Fig. 16.

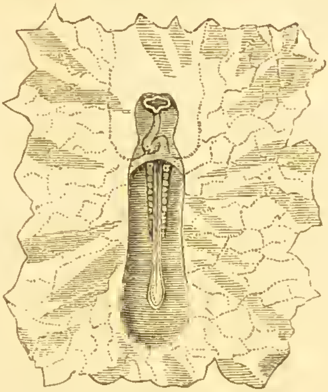


Fig. 17.

Fig. 16.—An Embryo twelve hours older than the former one. The primitive groove is now for the most part closed over. The first brain-cell is widened out laterally, and bent forwards. The posterior ones are altered in shape from absorption of fluid. There are ten vertebral cells. At both ends of the primitive groove folds of the serous layer are visible—the commencement of the amnios. The serous layer is cut close round the embryo ; and upon the mucous layer, fine lines, in the form of a network, are visible—the commencement of the *vascular layer.* (10 *diam.*)

Fig. 17.—The same Embryo turned round and examined on the under or abdominal surface. The head with the broadened-out first brain-cell is seen coming forward. Immediately below this an S-shaped tube is seen, which is the rudimentary heart. The lower end branches off on each side to join the vascular network, forming the *venæ omphalo-mesentericæ.* The visceral or abdominal cavity is seen open below, causing the embryo to resemble somewhat the appearance of a partly-decked boat. (10 *diam.*)

bryo heart and aorta (figs. 18 and 19), and a circulation is established, which extends over the entire ovum, with the exception of its two poles (fig. 20). The embryo now is

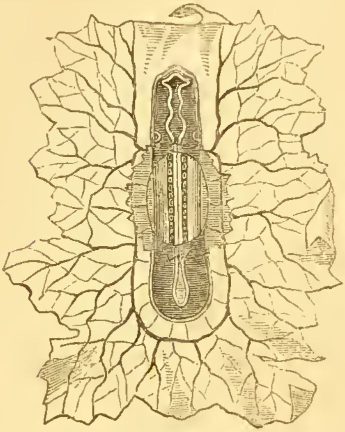


Fig. 18.

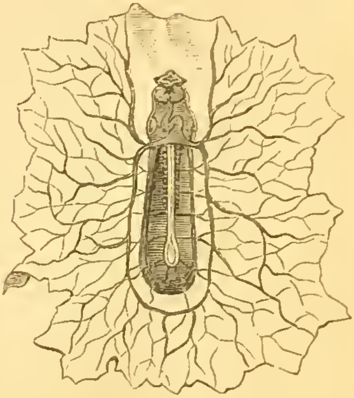


Fig. 19.

Fig. 18.—An Embryo from an Ovum supposed to be twenty-three or twenty-four days old, seen from above. The primitive groove is now completely closed, to form the medullary tube, and exhibits above the three primitive brain-cells. The first of these is seen to be so expanded laterally as to form at each side the embryo eyes. The embryo ears are also seen on each side opposite the third brain-cell. The upper and lower ends of the embryo are now inclosed in a backward fold of the serous layer, which, however, is still open in the centre. The blood-vessels in the vascular layer are now fully formed. (10 *diam.*)

Fig. 19.—The same Embryo seen from below. The head is strongly bent forward, so that the first brain-cell and embryo eyes are best seen on this surface. Below these, two notched processes are seen, which are the first visceral arches. Below these again, the S-shaped heart—terminating, above in the aorta, below in the *venæ omphalo-mesentericæ.* The heart now pulsates, and a circulation is established over the vascular area. (10 *diam.*)

gradually raised above the surface of the germinal membrane, while the duplications and re-duplications of its three layers, which are constantly receiving thickness by cell growth, gradually produce the various organs and textures of the body. Three vesicles or sacs are formed in connection with them,—the *amnios* with the serous, the *allantois* with the vascular, and the *umbilical* with the mucous layer. The upper or serous layer of the germinal membrane may be observed from an early period to be reflected backwards, and from before backwards, as well as laterally,

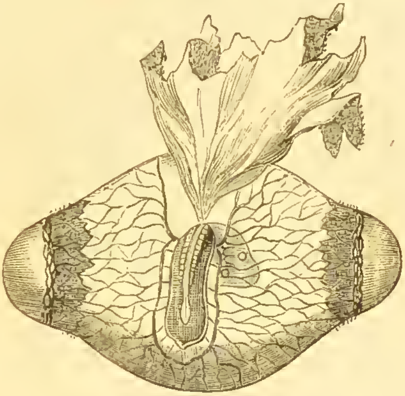


Fig. 20.

Fig. 20.—An entire Ovum, with the Embryo somewhat older than the last. The villous chorion is raised off the entire centre of the egg, which is suspended by it at one point, where the folds of the serous layer have completely closed over the back to form the amnios. The embryo lies with its inferior half in the plane of the vascular and mucous layers; whilst the head and superior half is prominent, and inclosed by them. At the sides are seen both the *arteriæ* and *venæ omphalo-mesentericæ*, which communicate with the plexus of the vascular layer, and terminate in circular rings, the *venæ terminales*, leaving the two poles of the ovum bare. (5 *diam.*)

gradually to inclose the embryo above (figs. 16 and 18). At length the layer closes, suspending the embryo as it were from one point (fig. 20), which, when it gives way, leaves a sac, which rises from the back of the embryo. This is the *amnios.* From the lower portion of the abdominal groove, and at the inferior extremity of the embryo, a swelling may now be observed (fig. 22, *bb*). This rapidly enlarges, and, at first open in the middle (fig. 23, *a*), coa-

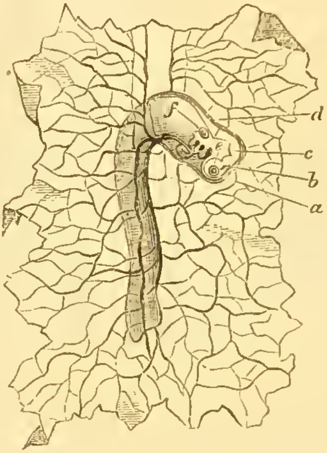
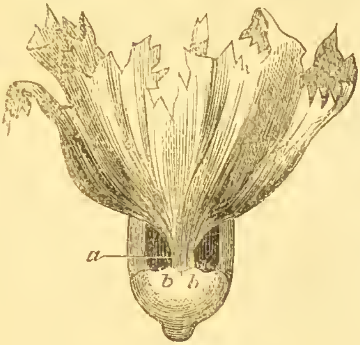


Fig. 21.

Fig. 21.—The same Embryo, removed with its membranes, and viewed from the internal surface of the ovum, sideways. The head and upper portion is seen surrounded by the amnios. In the head is observed the brain, divided into anterior, neighbouring, and middle brain, *a*, *b*, *c*; the third brain-cell, *d*; eyes, *e*; ears, *f*; not yet connected with the third brain-cell. There are three visceral arches. The heart is further developed, prominent, and surrounded by the serous membrane. The lower portion of the embryo is covered with the vascular and mucous layers. (5 *diameters.*)

lesces to form another sac, which hangs out of the lower portion of the abdominal opening. This is the *allantois* (fig. 24). About the same time the inferior layer of the



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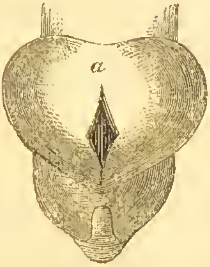

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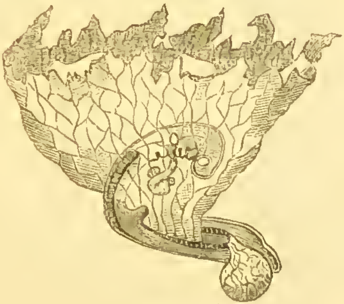

Fig. 24.

Fig. 22.—The Lower End of an Embryo some hours older than that in the last figure. The mucous and vascular layers are drawn upwards, so that not only is the visceral cavity seen, but the lower portion of the intestinal canal, *a*. At the lower portion of the embryo are two small swellings, *b*, *b*, the commencement of the *allantois*. (10 *diam.*)

Fig. 23.—The Lower End of an Embryo twelve hours older than the last. The *allantois* now forms a sac, the two halves of which, however, are not yet closed. (10 *diameters.*)

Fig. 24.—The Embryo of an Ovum twelve hours older than the germinal membrane, more or less constricted when it comes out of the abdomen of the embryo, forms a third sac or vesicle, called the *umbilical sac.* The mode of formation and relation of these three sacs will be better understood from the accompanying diagram (fig. 25).

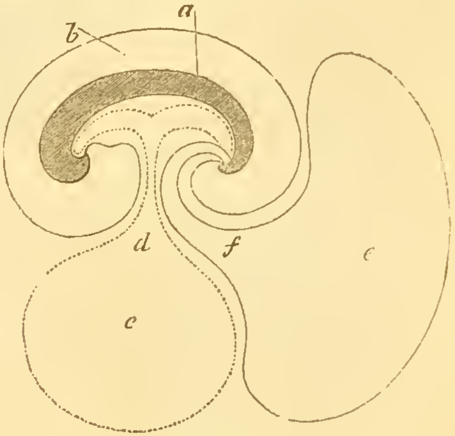

Fig. 25.

The various parts of the body are now rapidly perfected, to the principal of which we may shortly allude:—1*st*, The *chorda dorsalis*, inclosed by the *dorsal laminæ*, which forms the cranio-vertebral canal, are developed below

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last, suspended by the vascular and mucous layers. All the different parts formerly referred to may be seen further developed. The superior extremity is prominent. In the visceral cavity two long striated bodies are seen, the *Wolffian bodies* ; and the allantois is now so enlarged as to hang out of the visceral cavity, covered with a network of vessels in connection with the vascular layer. (5 *diam.*)

Fig. 25.—Diagram representing the mode of formation and position of the three Embryonal Sacs. *a*. Embryo—*b*. Amnios—*c*. Umbilical Vesicle—*d*. the Vitelline Duct, or Pedicle of the Umbilical Vesicle—*e*. Allantois—*f*. The Urachus or Pedicle of the Allantois, afterwards the Urinary Bladder.

into spinal cord and vertebræ, while superiorly are produced the cerebrum, cerebellum, and cranium (fig. 21, *b*, *c*, *d*; and fig. 24). 2*d*, The bent tube, which originally formed the heart, is by a kind of notch first separated into heart and aorta; and the former, by the growth of internal septa, divided into ventricles and auricles. 3*d*, The formation of branches from the aorta, which go to the branchial arches or clefts (fig. 26). 4*th*, The union of these branchial arches to form the bones of the face and jaws. 5*th*, The development of the special senses. 6*th*, The formation first, of the upper extremities (fig. 24), and, secondly, of the lower (fig. 27). 7*th*, The appearance of two

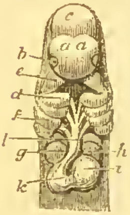

Fig. 26.

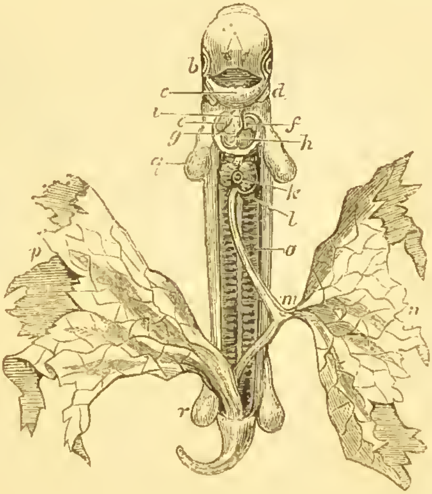

Fig. 27.

Fig. 26.—The Head of the same Embryo represented in fig. 24, seen in front. *a*. Anterior Brain-Cells—*b*. Eyes—*c*. Second Brain-Cell—*d*. First Visceral Arch—*e*. Process thereof—*f*. Three Lower Visceral Arches—*g*. Right, and *h*, Left Auricle—*i*. Left, and *k*. Right Ventricle—*l*. Aorta, with aortic branches to the visceral arches. (10 *diam.*)

Fig. 27.—An Embryo older than the last, seen in front. *a*.

striated organs deep in the visceral cavity, called Wolffian bodies, which are afterwards transformed into the genito-urinary organs (fig, 27, *o*). 8*th*, The inflexions and constriction of the mucous layer to produce the alimentary canal (fig. 27, *m*). And, *finally*, the enlargement of the various glands and internal viscera, and the greater perfection of all

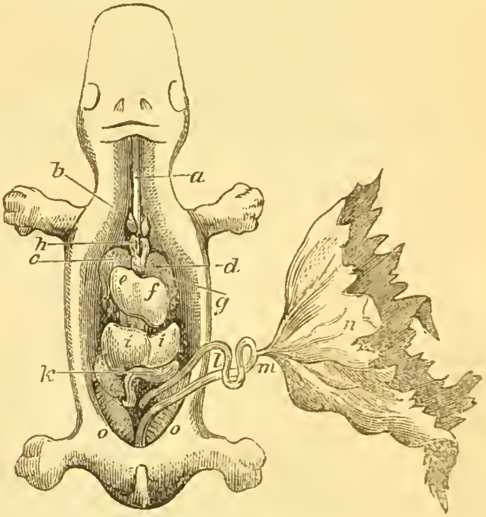

Fig. 28.

the parts referred to (fig. 28); while the abdominal opening, closing in front, leaves only a small aperture, through

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Nasal Apertures—*b*. Eyes—*c*. First Visceral Arch, now the Under Jaw—*d*. Second Visceral Arch—*e*. Right, and *f*. Left Auricle—*g*. Right, and *h*. Left Ventricle—*i*. Aorta—*k*. Liver; between its two lobes is seen the cut *Vena Omphalo-Mesenterica*—*l*. Stomach—*m*. Intestinal Canal, terminating in the Umbilical Vesicle—*n*, *o*. Wolffian Bodies—*p*. Allantois—*q*. Upper, and *r*. Under Extremity. (5 *diam.*)

Fig. 28.—Embryo of an egg about four weeks old. *a*. Trachea and Œsophagus—*b*. Thymus Gland—*c*. Right, and *d*. Left Auricle—*e*. Right, and *f*. Left Ventricle—*g*. Left, and *h*. Right Aorta—*i*, *i*, *i*. Three Lobes of the Liver—*k*. Stomach which the united pedicles of the allantoid and umbilical sacs pass to constitute the umbilical cord. To describe each of these processes at length, or the variation which has been shown to exist in them, among the leading tribes of animals, would lead us too far. It will suffice to say, that from the serous layer is principally formed the nervous centres and the organs of sense; from the vascular layer for the most part is produced the voluntary and non-voluntary muscles, the bones, and the blood-vessels; and from the mucous layer, the mucous surfaces and chief portion of the glands.

Besides the changes which occur within the ovum, and which result in the formation of the embryo, there are others which seem external to it, and which are indirectly very necessary to its formation. As the impregnated ovum descends the Fallopian tube towards the uterus, it becomes covered with an albuminous layer, called the *chorion;* and on passing into that organ, encounters another which lines it, called the *decidua.* When the allantoid sac becomes developed, it sends vessels into a portion of these membranes to form the *placenta,* the relations of which to the various sinuses of the uterus are of a kind that enable the mother to furnish blood to the fœtus by transudation of its fluid substance through a double membrane. The uterus also becomes greatly enlarged and thickened; numerous non-voluntary contractile fusiform cells are formed in it; and at length, the fœtus having arrived at maturity, these commence to contract, and, by a series of expulsive efforts, finally expel the infant. The mammary glands also gradually enlarge, so that about the period of birth they are

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—*l.* Intestinal Coils, which by a band *m* (the former *Ductus Omphalo-Mesentericus*), are in connection with the umbilical vesicle *n*—*o.* Wolffian Bodies. (5. *diam.*)

fitted to furnish a copious supply of milk, under the stimulating action of suction, to which the infant is instinctively impelled for the sake of nourishment.

Such is a general sketch of the various stages of the function of reproduction, a study of which in the different classes of animals has led to the formation of various ingenious hypotheses, whereby it has been sought to bring the order of evolution within the operation of certain laws. One of these, which has excited great attention, is, that the human fœtus passes through transition periods resembling in turn the different inferior beings of the animal scale: that is to say, it at first resembles a zoophyte, then a mollusc, then a worm, a fish, a reptile, and so on. Thus the monads found among the inferior animals have been supposed to be represented by the germinal vesicle. The yolk, when divided, has been thought to resemble a gonium or a volvox. When the primitive groove closes, it has been likened to a worm; afterwards to a molluscous animal; and when the visceral arches appear, to a fish; and so on. This method of viewing the phases of development has led to a generalization thus expressed by Serres,—viz., that "Human organogenesis is a transitory comparative anatomy, as in its turn comparative anatomy is a fixed and permanent state of the organogenesis of man." But that the human embryo ever resembles a worm, a mollusc, reptile, fish, or bird, can on careful examination nowhere be recognised. It is true, that at one period all ova resemble each other; but it is equally certain that from the first moment of their formation they are impressed with a power of developing themselves only in one direction, so that the ovum of a reptile, fish, or bird will always be developed into similar animals, and by no concurrence of circumstances will ever be transformed into different ones. Neither is there any anatomical or structural relation between them, for the visceral arches in the human fœtus are in no way, as has been supposed, analogous with the branchiæ or lungs of the fish, for the former are transformed into the bones of the face, while lungs originate in inflexions of the mucous layer. The theory, then, may be considered as more fanciful than real, and founded upon loose analogies, which, instead of being strengthened, are weakened as development proceeds, and the true types of such analogies become more evident.

In recent times another theory has been brought forward, denominated *alternate generation* by Steenstrup, but more correctly *parthenogenesis* by Owen. Many of the facts described by the former refer not so much to an alternate as to a continuous development. Thus, many insects spend part of their lives as a worm, and part as a moth. The moth produces the worm, and the worm produces the moth; but this is not an alternate, but a different phase of the same generation. So a correct knowledge of the development of the *Medusa aurita* has shown that what naturalists had considered to be four distinct animals are in fact only different stages in the development of one animal. The formation of the Aphis is especially alluded to by Steenstrup, several of which insects are produced from the mother, and each of which may produce others, although it is only certain of them which become transformed into a fly. But the generation of a plant may be called alternate in the same sense as it is used in the case of the Medusa or the Aphis, inasmuch as the seed produces a leaf and a root, which proceeds to develop other leaves before it finally produces the flowers with the seed like that from which the plant originated. The term *parthenogenesis* (παρθενεία, *virginity*), as expressive of the power of reproduction in various forms without the act of fecundation, is therefore the more correct one.

This doctrine has now led to many important results, among which the discovery of the origin and mode of reproduction of tape-worms, and the manner in which the three kinds of bees are produced, are good examples. It is now known that certain Entozoa are partly developed in one animal and partly in another. Thus, the minute eggs of certain Tœniæ, or tape-worms, enter the body of the mouse, and are converted into cystic worms, which have been considered as distinct creatures. In this stage they would remain in that animal; but the mouse being eaten by the cat, the cystic worm of the former is converted into a tape-worm in the body of the latter. In the same way, the *Cysticercus pisiformis*, found in hares and rabbits, is converted into the *Tœnia pisiformis*, so common in the fox, which feeds on those animals; and the *C. cellulosæ*, so frequent in the flesh of pork and of mutton, is transformed into the *Tœnia Solium* of man. Thus the mystery as to the origin of tape-worm has been cleared up; and the practical result, that if we desire to cure the disease, besides giving anthelmintics and purgatives, we must also prevent the eating of flesh underdone, or game and fish out of season, when it is likely to be infected with *Cysticerci*. So, among bees it has been shown by Dzierzon and Siebold that the queen-bee, during her nuptial flight, receives the semen of the male into a receptacle communicating with the oviducts, but from which it can be shut off at will. The workers having prepared three kinds of cells,—namely, drone-cells, worker-cells, and royal-cells, each of which has its own peculiar form and size,—the queen deposits an egg in each. In doing this, she takes care to bring every one of those destined for the royal and the worker cells into contact with the seminal fluid, but takes equal care to keep free from such contact every one of those destined for the drone-cells. It has also been shown that a worker-bee can be transformed into a queen by feeding it on a peculiar kind of food. It follows that male animals in insects may be produced independent of the union of the ova with spermatozoids, in the same way that buds are thrown out in trees, or polype heads formed without fecundation. The queen-bee in this respect is like a tree, uniting two kinds of development, oviparous and gemmiparous. Her ovary resembles a *gemmarium*, the products of which she fertilizes at will by shedding on the ovum the semen stored up in her receptacle.

The modern researches into reproduction, therefore, indicate that the tribes of animals hitherto described by naturalists are not so numerous as was once thought, and that many of them are only the metamorphic changes of one creature. They show that animals as well as plants can propagate in two ways—by buds and by germs; the individual developed from the bud being capable of producing an ovum from which another individual may spring that may produce a bud. Thus much of the mystery that has shrouded the origin of many animals has been dissipated, and the arguments by which it has been sought to establish a spontaneous or equivocal generation overthrown. They also confirm the instinctive convictions, so long established among the human race, which point to the male as being not merely the head and proper representative of the species, but the real reproducer of it also. The man being the head of the woman; she merging in him, and having no rights apart from him; their joint offspring, not hers, but truly his; born indeed of her, but begotten by him. The daughter, equally with the son, represents their common father, but her children do not. They must be looked upon as representing mainly the husband, whose name, accordingly, they bear. Hence the truth of the long-confirmed notion of descent in the male line, which, coupled with the instinct of power, has given rise to the law of primogeniture. According to Blackstone, "The husband and wife are one person in law; that is, the very being or legal existence of the woman is suspended during the marriage." Science, jurisprudence, and religion, therefore, unite in proving that the wife is part of the husband; the two being, in the language of Scripture, "no more twain, but one flesh." (A. Harvey.)

PART THIRD

PATHOLOGICAL PHYSIOLOGY.

Every animated being has a limited period of existence, during which it is constantly undergoing a change. So long, however, as this change takes place uniformly in the different parts of which it is composed, its physiological or healthy condition is preserved. But immediately the action of one organ becomes excessive or weak in proportion to the others, disease, or a pathological state, is occasioned. This state may be induced by direct mechanical violence, but may also occur from the continued or irregular influence of several physical agents, such as temperature, moisture or dryness, quality of the atmosphere, kind of food, &c., &c. These are always acting upon the vital powers of the individual as a whole, as well as incessantly stimulating the various organs to perform their functions. We have previously seen that life may be defined in the words of Béclard—" Organization in action." Health is the regular or normal, and disease the disturbed or abnormal condition of that action.

While such may be assumed to be our notion of disease in the abstract, what constitutes disease in particular has been much disputed. From the time of Hippocrates to that of Cullen and his followers, the external manifestation or symptoms constituted the only method of recognising diseased action, and gradually came to be regarded as the disease itself. Then these symptoms were arranged into groups, divided, subdivided, and named, according to the predominance of one or more of them, or the mode in which they presented themselves. These artificial arrangements are the nosologies of former writers. All philosophical physicians, however, have recognised that the true end of medical inquiry is, if possible, to determine rather the altered condition of the organs which produces the disordered function, than to be contented with the study of the effects they occasion. But the difficulty of this inquiry has been so great, and a knowledge of the means of prosecuting it so limited, that it is only within the last thirty years medicine has been enabled to build up for herself anything like a solid scientific foundation. What has hitherto been accomplished in this way has been brought about by the conjoined cultivation of morbid anatomy, pathology, and clinical observation, greatly assisted, however, by the advance of numerous collateral branches of science, and especially in recent times by chemical and histological investigation. The result has been a complete overthrow of nosological systems. We now attempt to trace all maladies to their organic cause; and doubtless in proportion as this has been successfully accomplished, medicine has become less empirical and more exact. The organic changes, however, which produce or accompany many diseases have not yet been discovered, and consequently a classification of all maladies on this basis cannot be strictly carried out. The organic cause of epilepsy, hydrophobia, and of many fevers, for example, is as yet unknown. When, therefore, the morbid change in an organ is unequivocally the origin of the symptoms, we employ the name of the lesion to designate the disease; but when there is disturbance of function, without any obvious lesion of a part, we still make use of the principal derangement to characterize the malady. Thus, as regards the stomach, we say a cancer or an ulcer of that viscus, and thereby express all the phenomena occasioned. But if we are unable to detect such cancer or ulcer, we denominate the affection after its leading symptom,—dyspepsia, or difficulty of digestion.

In endeavouring to carry out this distinction, however, modern pathologists have fallen into a great error, inasmuch as they have continued to employ the nomenclature of our forefathers, and use words simply expressive of the presence of symptoms, to indicate the altered condition of organs which are the cause of those symptoms. Formerly the term *inflammation* meant the existence of pain, heat, redness, and swelling ; it now means certain changes in the nervous, vascular, and parenchymatous tissues of a part. Formerly, apoplexy meant sudden unconsciousness originating in the brain ; now it is frequently used to express hæmorrhage into an organ ; and hence the terms apoplexy of the lung and of the spinal cord. The two ideas are essentially distinct, and bear no reference to each other, because the same word may be, and often is, employed under circumstances where its original meaning is altogether inapplicable, and even when the symptoms it was intended to express are altogether absent. Hence it is incumbent on every one who applies to organic changes terms which have been long employed in medicine, to define exactly what he means by them. In this way, old indefinite expressions, though still retained, will have a more precise meaning attached to them.

But notwithstanding the confusion which has necessarily resulted from the rapid advance of medicine in late years, and from the frequent change of ideas with regard to the nature of morbid actions, it still is correct to say that disease is only an alteration in the healthy function of organs. Hence all scientific classification of maladies must be founded on physiology, which teaches us the laws that regulate those functions; and they may be divided, like the functions themselves, into—1*st*, Diseases of Nutrition; 2*d*, Diseases of Innervation; and 3*d*, Diseases of Reproduction.

DISEASES OF NUTRITION.

The various modes in which nutrition becomes impaired can only be understood by knowing the different steps of the nutritive process. For ages medical men have been in the habit of considering the blood to be the primary source of numerous maladies. But our previous description of the process of nutrition must show that the changes in this fluid, and the diseases which accompany them, are for the most part not primary, but secondary; that is to say, they are dependent on previously existing circumstances, to the removal of which the medical practitioner must look for the means of curing his patient. This will become apparent, not so much by analysing the individual disorders to which the various organs and tissues of the body are liable, as by describing the fundamental pathological processes which are common to all parts of the frame. An enumeration and definition of these appear necessary in the first place.

Classification of Diseases of Nutrition.

CONGESTION, OR EXCESS OF BLOOD IN A PART.—This is an over-distension of the blood-vessels, but more especially of the capillaries, with blood. It may be caused by excitement of the nervous system, by mechanical impediments which obstruct the return of venous blood, or by irritation of the textures. However produced, congestion may be temporary, and disappear without producing much disturbance, or, if long continued, it may give rise to one or more of the following conditions :—

FEVER.—When congestion is caused or accompanied by general excitement of the nervous system, it produces fever, a morbid condition characterized by hot skin, accelerated pulse, furred tongue, thirst, and headache,—phenomena usually preceded by a sensation of cold, or rigor. If caused by some poison introduced through the blood, it is called *primary*, the principal forms being *intermittent*, *remittent*, and *continued.* If produced by injuries to texture, either directly from violence, or indirectly from reflex action causing internal inflammations, it is denominated *secondary* or *symptomatic.*

DROPSY, OR EFFUSION OF SERUM.—When congestion is *passive*, or caused by mechanical obstruction to the flow of blood through the veins, serum transudes through the walls of the capillary vessels, and collects in various places, causing dropsy. If generally diffused, especially through the subcutaneous tissue, it is called *anasarca;* if limited to the peritoneal cavity, *ascites;* if local, *œdema.*

HÆMORRHAGE, OR EXTRAVASATION OF BLOOD.—This may arise from direct injury to a blood-vessel, from a wound, or from disease of its coats. Under such circumstances it may be *arterial* or *venous*, the former distinguished by the blood being of a bright florid, and the latter by its being of a claret colour. The capillaries are frequently ruptured from over-distension with blood, which is *capillary* or *congestive* hœmorrhage, causing dropsical effusions or inflammatory exudations to assume a sanguinolent character.

INFLAMMATION, OR EXUDATION OF LIQUOR SANGUINIS.—When congestion is *active*, or arises from irritation of the textures, it may, if excessive, terminate in the exudation through its coats of the *liquor sanguinis.* This is inflammation; an expression still used very vaguely by some pathologists, but which, thus defined, separates the morbid state accurately from congestion or fever on the one hand, and from dropsy, or the processes of growth, on the other. The exudation thrown out undergoes a variety of changes, producing various morbid conditions, according as it lives or dies.

SIMPLE OR INFLAMMATORY EXUDATION.—This consists of the normal *liquor sanguinis*, which infiltrates the neighbouring tissues or collects in serous cavities. It then coagulates, and may undergo the following vital transformations:—1*st*, Into cells and fibres, forming *adhesive lymph*, as on the surface of serous membranes; 2*d*, Into pus-cells, constituting *suppuration*, as in mucous surfaces or in areolar texture; 3*d*, Into granule-cells, forming *inflammatory softening;* and 4*th*, Into various elementary tissues, such as the fibrous, vascular, cartilaginous, bony, &c. In this manner, the exudation may be (1.) absorbed, or undergo *resolution;* (2.) evacuated externally by discharge; or (3.) assimilated to the body. It is the agent which forms abscesses, causes the healing of wounds, and the union of divided tendons, bones, &c.

TUBERCLE, OR TUBERCULAR EXUDATION.—When an exudation, instead of undergoing the vital changes just referred to, assumes a yellow or grayish aspect and cheesy consistence, it is called *tubercle.* It consists of solid irregularly-formed bodies, called *tubercle corpuscles*, more or less associated with molecules and granules. If disseminated in small grains, it is called *miliary;* if in considerable patches or masses, it is *infiltrated tubercle.* When chronic, it may be *encysted*, or present the form of *cretaceous* or *calcareous masses.*

CANCER, OR CANCEROUS EXUDATION.—When an exudation, instead of undergoing the vital transformations previously described, passes into cells and fibres, the former increasing endogenously, it is called *cancer.* If hard, and principally formed of fibres from associated morbid growth, it is called *scirrhus;* if soft, often yielding a milky juice on pressure, it is *encephaloma;* if having a fibrous basis, this is so arranged as to form areolæ or loculi, containing a gelatinous gum or glue-like matter; then it is called *colloid cancer.*

MORTIFICATION, OR MOIST GANGRENE.—When the exudation is poured out rapidly in such quantity as to paralyse the nerves, obstruct the blood-vessels, and prevent the return of circulation in them, it dies, and undergoes chemical putrefactive changes, and is said to be mortified, or to be affected with moist gangrene. It differs from dry gangrene, which is slow death of pre-existing texture from want of nourishment. Sometimes it is epidemic, from external or unknown causes, resembling the blight which affects vegetables.

ULCERATION.—When an exudation does not pass into the vital transformations formerly described, but presses upon the surrounding parts, obstructing the flow of blood in them, death of such parts takes place. Under these circumstances, the whole slowly disintegrates; loss of texture is occasioned, with breach of continuity; and an *ulcer* is formed. Ulceration may also be produced by the direct pressure of a foreign body, continued weight of depending parts, &c.

MORBID GROWTHS OF TEXTURE.—Increased growth of tissues may assume various forms: the organ or structure may be enlarged in whole or in part, still maintaining more or less of its original texture, shape, and function—constituting *hypertrophy.* Membranes may become preternaturally thickened, causing more or less *induration*, whereby the movements of parts may be affected; or the calibres of tubes and ducts may be diminished, producing *stricture*. The vital transformations of an exudation into pus, granule, or other cells, must be regarded as a form of morbid growth, as must the results of the healing process, which give rise to new tissues exactly resembling those previously existing in other parts of the body,—as in cicatrices, callus, &c. Lastly, such growths may assume the form of *tumour*. Morbid growths may be classified into—1*st*, *Fibroma*, or fibrous growths; 2*d*, *Lipoma*, or fatty growths; 3*d*, *Angionoma*, or vascular growths; 4*th*, *Cystoma*, or cystic growths; 5*th*, *Adenoma*, or glandular growths; 6*th*, *Epithelioma*, or epithelial growths; 7*th*, *Echondroma*, or cartilaginous growths; 8*th*, *Osteoma*, or osseous growths; and 9*th*, *Carcinoma*, or cancerous growths.

MORBID DEGENERATIONS OF TEXTURE.—This also may assume various forms. The organ or structure may be diminished in whole or in part, constituting *atrophy*, still, however, retaining its normal shape and function; or the structure of the parts themselves may have undergone alterations, whereby their functions are impaired or destroyed. Such degenerations are of four kinds:—1*st*, They may, in a variety of ways, become indurated and shrivelled up, or converted into a waxy or glue-like material, apparently from an excess of one or more of the albuminous or gelatinous compounds. This is *albuminous degeneration*. 2*d*, They become softer, from an accumulation of fatty granules, either within cells or among the minute elements of the texture. This is *fatty degeneration*. 3*d*, In the same manner, pigment of various kinds is deposited in or replaces the tissue, which may be red, yellow, brown, green, blue, purple, or black, owing to chemical changes ascribable to extravasated blood or bile, or to some peculiar secretion. This is *pigmentary degeneration.* *Lastly*, the tissues may become infiltrated with mineral matter of various kinds, but generally with salts of lime in solution, which subsequently becoming solidified, impede or destroy function. Such is *mineral degeneration.*

CONCRETIONS.—These are non-organized and non-vascular productions, formed by the mechanical deposition and aggregation of various kinds of matter, generally in the ducts or cavities of the hollow viscera. They may be composed of albuminous, fatty, pigmentary, or mineral substances, but are separable from degenerations from their never being formed out of an organic structure. *Urinary concretions*, or calculi, are composed of the salts which are too predominant in the urine, and which have been precipitated round a central body or nucleus, formed within or introduced from without. *Intestinal concretions* are usually composed of hair or vegetable fibres, which have been swallowed and accumulated also round a central nucleus. *Mineral concretions*, composed of carbonates and phosphates of lime, are common in the mucous passages of various organs, especially the salivary, bronchial, pancreatic, hepatic, and renal. They also occur in the veins, when they are called *phlebolites.* Occasionally they resemble starch grains, and are called *amyloid;* and not unfrequently concretions are found really composed of aggregated or isolated starch corpuscles, which may be called *amylaceous.*

PARASITIC GROWTHS.—These are of two kinds, vegetable and animal. The vegetable parasitic growths may be divided into such as grow on the surface (*Epiphyta*), or those that have been formed in the interior of the body, chiefly on the mucous surfaces (*Entophyta*). The animal parasites may also be divided into such as infest the surface (*Epizoa*), and such as are found in the interior of the body (*Entozoa*). To the former belong the several species of *Pediculus*, or louse; the *Acarus Scabiei*, or itch-insect; the *Entozoon folliculorum*, which inhabits the follicles of the skin; and the *Pulex penetrans*, or guinea-worm. The Entozoa are numerous, and may be divided into—1*st*, *Cystica*, or saccular worms; 2*d*, *Cestoidea*, or chain-worms; 3*d*, *Trematoda*, or flat worms; and 4*th*, *Nematoda*, or thread-worms.

Such is an enumeration and definition of the organic diseases of textures and organs. What are called *functional disorders* of the same parts are such as leave no traces of their existence after death, and are for the most part simple excess or diminution of normal actions. It is only when these last lead to congestions and exudations, terminating in fever or vital transformations, and chemical changes producing degenerations, that a true structural lesion can be said to exist. The causes of these organic alterations of texture are to be sought—1*st*, In increased or diminished stimulation acting directly on the tissues themselves; 2*d*, In increased or diminished excitability of the nervous system operating upon them indirectly; 3*d*, In an altered condition of the blood; and 4*th*, In chemical transformations of texture. These may act separately or combined, and one may occasion the other. We shall treat of these causes under the following heads:—

Theory of Congestion.

Congestion may be passive or active,—the former leading to effusion of serum, or dropsy, the latter to exudation of the *liquor sanguinis*, or inflammation.

Passive congestion is caused by all those circumstances which impede the circulation through the veins, such as ligatures or tumours, which press upon a large vein coming from a limb; swellings or diseased liver, which obstruct the abdominal veins; cardiac disorders, which obstruct the return of blood from the lungs; or renal and integumentary disease, which check the excretion of water from the system.

Active congestion in the capillaries has, however, excited the greatest discussion, in consequence of the difficulty of determining its nature, as well as of the vast importance which belongs to it both in the science and practice of medicine. Indeed a knowledge of this subject may be said to be the pivot on which, in all ages, the medical philosophy of the time has revolved. A careful consideration of it, therefore, is necessary.

When we irritate the web of a frog's foot, it may be seen, under the microscope, that—1*st*, The capillary vessels are narrowed, and that the blood flows through them with greater rapidity. 2*d*, The same vessels become enlarged, and the current of blood is slower, although even. 3*d*, The flow of blood becomes irregular. 4*th*, All motion of the blood ceases, and the vessel appears fully distended. 5*th* and *lastly*, The *liquor sanguinis* is exuded through the walls of the vessel, sometimes accompanied by extravasation of blood corpuscles, owing to the rupture of the capillaries.

The first step in the process,—viz., narrowing of the capillaries,—is readily demonstrated on the application of acetic acid to the web of the frog's foot. If the acid be weak, the capillary contraction occurs more slowly and gradually. If it be very concentrated, the phenomenon is not observed, or it passes so quickly into complete stoppage of blood, as to be imperceptible. Although we cannot see these changes in man under the microscope, certain appearances indicate that the same phenomena occur. The operations of the mind, for instance, as fear and fright, and the application of cold, produce paleness of the skin; an effect which can only arise from contraction of the capillaries, and a diminution of the quantity of blood they contain. In the majority of instances, also, this paleness is succeeded by increased redness, the same result as follows from direct experiment on the web of the frog's foot, constituting the second step of the process. In other cases, the redness may arise primarily from certain mental emotions, or from the application of heat. In either case, it depends on the enlargement of the capillaries, and the greater quantity of blood they contain.

It has been asserted that, instead of contraction of the capillaries, the first changes observable are enlargement, with an increased flow of blood. To determine positively the question of contraction or dilatation, I made a series of careful observations on the web of a frog's foot. Having fixed the animal in such a way that it could not move, I carefully measured with Oberheuser's eye micrometer the diameter of various vessels before, during, and after the application of stimuli. The results were, that immediately hot water was applied, a vessel that measured thirteen spaces of the eye micrometer contracted to 10; another that measured 10 contracted to 7; a third that measured 7 contracted to 5; a fourth, which was a capillary carrying blood globules in single file, and measured 5, was contracted to 4; and another, one of the smallest size, which measured 4, was contracted to 3. With regard to the ultimate capillaries, it was frequently observed that if filled with corpuscles, they contracted little, but if empty, the contraction took place from 4 to 2; so that no more corpuscles entered them, and they appeared obliterated. This was especially seen after the addition of acetic acid.

It was also observed that minute vessels that contracted from 4 to 3 afterwards became dilated to 6 before congestion and stagnation occurred. The smaller veins were seen to contract as much as the arteries of the same size.

The variation in the size of, and amount of blood in, the capillaries is conjoined with changes in the movement of that fluid. Whilst the vessels are contracted the blood may be seen to be flowing with increased velocity. After a time the blood flows more and more slowly, without, however, the vessel being obstructed: it then oscillates,—that is, moves forwards and backwards, or makes a pause, evidently synchronous with the ventricular diastole of the heart. At length the vessel appears quite distended with coloured corpuscles, and all movement ceases.

Again, these changes in the movement of the blood induce variations in the relation which the blood corpuscles bear to each other, and to the wall of the vessel. In the natural circulation of the frog's foot, the yellow corpuscles may be seen rolling forward in the centre of the tube, whilst on each side a clear space is left, only filled with *liquor sanguinis* and a few lymph corpuscles. There are evidently two currents, the centre one very rapid, that at the sides (in the lymph spaces, as they are called) much slower. The coloured corpuscles are hurried forward in the first, occasionally mixed with some lymph corpuscles. These latter, however, may frequently be seen clinging to the sides of the vessel, or slowly proceeding a short distance down the tube in the lymph space, and then again stopping. Occasionally they get into the central torrent, when they start off with great velocity, and accompany the yellow corpuscles. It has been said that these corpuscles augment in number, accumulate in the lymph spaces, and obstruct the flow of blood. In young frogs their number is very great; but then they constitute a normal

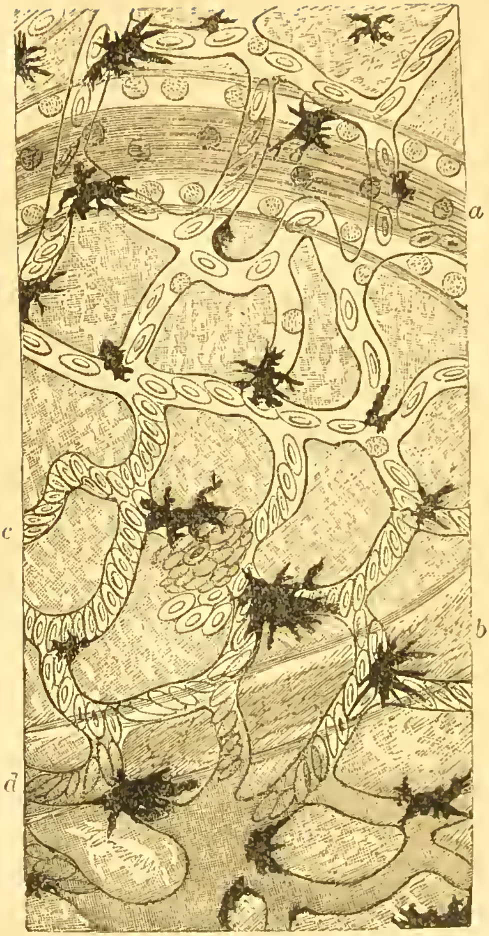

Fig. 1.

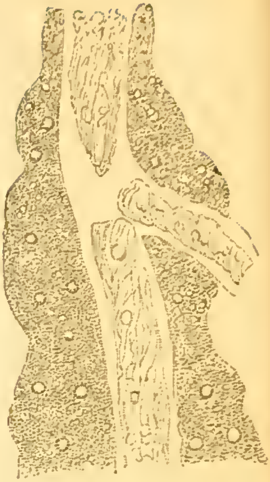

Fig. 2.

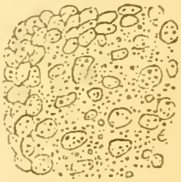

Fig. 4.

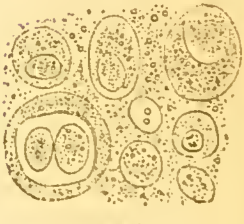

Fig. 5.

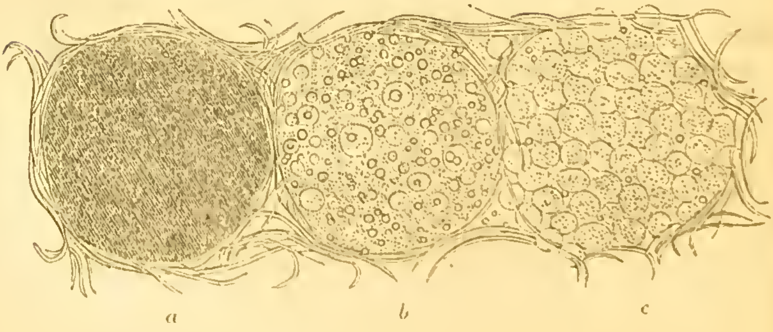

Fig. 3.

Figure 1.

An exact copy of a portion of the Web in the Foot of a Young Frog, after a drop of strong alcohol had been placed upon it.—The view exhibits a deep-seated artery and vein, somewhat out of focus; the intermediate or capillary plexus running over them, and pigment cells of various sizes scattered over the whole. At the top of the figure the circulation is still active and natural. About the middle it is more slow, the column of blood is oscillating, and the corpuscles crowded together. At the bottom, congestion, followed by exudation, has taken place.—*a*. A deep-seated Vein, partially out of focus. The current of blood is of a deeper colour, and not so rapid as that in the artery. It is running in the opposite direction. The lymph space on each side, filled with slightly yellowish blood plasma, is very apparent, containing a number of colourless corpuscles, clinging to or slowly moving along the sides of the vessel.—*b*. A deep-seated Artery, out of focus, the rapid current of blood allowing nothing to be perceived but a reddish-yellow broad streak, with lighter spaces at the sides.—Opposite *c*, laceration of a capillary vessel has produced an extravasation of blood, which resembled a brownish-red spot.—At *d*, congestion has occurred, and the blood corpuscles are apparently merged into one semi-transparent, reddish mass, entirely filling the vessels. The spaces of the web, between the capillaries, are rendered thicker and less transparent, partly by the action of the alcohol, partly by the exudation. This latter entirely fills up the spaces, or only coats the vessel. (200 *diam.*)

Figure 2.

A Blood-Vessel from an inflamed brain, coated with coagulated exudation.

Figure 3.

Three Air Vesicles from an inflamed lung.—*a*. Coagulated exudation; *b*. Cells forming in the exudation; *c*. Cells (*pus-cells* fully formed.

Figure 4.

Corpuscles in a tubercular exudation from the mesenteric gland.

Figure 5.

Cells, multiplying endogenously, in a cancerous exudation, from the uterus.

part of the blood, and in no way impede the circulation. In old frogs, on the other hand, all these, and subsequent changes, may be observed, without the presence of colourless corpuscles. When the capillaries enlarge, however, the central coloured column in the smaller vessels may be seen to enlarge also, and gradually approach the sides of the tube, thus encroaching on the lymph spaces. The slower the motion of the blood, the closer it comes, until at length the coloured corpuscles come in contact with the sides of the vessel, and are more or less compressed and changed in form. At last the vessel is completely distended with coloured corpuscles, the original form of which can no longer be discovered, and the tube appears to be filled with a homogeneous deep crimson fluid. This is congestion. The different changes leading to it may be explained as follows:—

1. The contraction and dilatation of the capillaries are explicable by supposing them to be endowed with a power of contractility analogous to that existing in non-voluntary muscles. John Hunter thought they were muscular, from the results of his observations and experiments; and they may be shown by the histologist to consist of a delicate membrane in which permanent nuclei are imbedded. In structure, then, they closely resemble the muscular fibres of the intestine, and we know that, like them, they may be contracted or dilated by emotions of the mind—that is, through the nerves; or by local applications—that is, directly. The narrowing of these tubes, therefore, may be considered, as Cullen thought it was, analogous to spasm; while their dilatation is similar either to the relaxation which follows such spasm or to muscular paralysis. The recent observations of Cl. Bernard and others as to the effects produced by dividing the large nervous trunk of the sympathetic in the neck have singularly confirmed this theory,

and shown how the modification of nutrition which characterizes *fevers* is probably owing to a morbid condition of the ganglionic nervous system.

2. The rapid and slow movement of the blood is explicable on the hydraulic principle, that when a certain quantity of fluid is driven forward with a certain force through a pervious tube, and the tube is narrowed or widened, while the propelling force remains the same, the fluid must necessarily flow quicker in the first case and slower in the second. It has been supposed, from the throbbing of large vessels leading to congested parts, that they pump a larger quantity of blood than usual into them. This was called "determination of blood" by the older pathologists, and is now known not to be a cause, but a result, of the changes going on in the capillary vessels and tissues of the affected part. The oscillatory movement, seen later in the transparent parts of small animals, has not been observed in man, and probably depends, in the former, on a weakened power of the heart.

3. It is the stoppage of the blood, and exudation of the *liquor sanguinis*, however, which it is most difficult to explain; for why, so long as there is no mechanical obstruction (and during this process none has ever been seen), should the circulation through the capillaries of a part cease? It has been endeavoured, indeed, of late years, to establish a mechanical obstruction, by supposing the formation of colourless corpuscles in large numbers, which cling to the sides of the capillaries, and so cause interruption of the stream. But this hypothesis is negatived by the following facts:—1*st*, In young frogs the vessels may be seen to be crowded with colourless corpuscles, while the circulation is in no way affected. 2*d*, In old frogs, oscillation and gradual stoppage of the stream may be seen, without any colourless corpuscles being present. 3*d*, The colourless

corpuscles, as shown by Remak, are increased, after large venesections, in the horse, without ever causing active congestion. And 4*th*, In leucocythemia, or white cell-blood, all the vessels are crowded with colourless corpuscles, and yet no active congestion in these vessels, nor exudation of any kind, has been occasioned.

We cannot ascribe the stoppage of the circulation in the capillaries to venous obstruction, or to mechanical pressure of any kind, because all observation proves that such causes, while they induce effusion of serum, never occasion exudation of *liquor sanguinis.* Neither can we suppose it to depend on endosmose, nor on a *vis à tergo*, as such physical causes cannot be shown to apply in all cases. We are compelled, therefore, to attribute the vital force producing these changes, not to anything residing in the blood or in the vessels, but in the tissues which lie outside the vessels. That these do possess a power attractive and selective, whereby matters are drawn from the blood to carry on nutrition and secretion, is now generally admitted in physiology. A modification of this power, whereby the attractive property is augmented, and the selective one diminished, at least offers us an explanation consistent with all known facts, and seems to be the only active agency to which we can ascribe the approach of the coloured particles to the capillary walls, and the passage through them of the exudation.

Theory of the Exudations.

The true cause of exudation, therefore, is irritation of texture, so modifying its vital properties that, instead of selecting and attracting from the blood simply what is necessary to keep up the nutritive processes, it draws out the entire *liquor sanguinis.* This coagulates, and if it do not die to produce mortification or ulceration, undergoes vital transformations, constituting what have been called the *terminations*, or *resulting phenomena* of inflammation in healthy persons, or tubercle and cancer in certain constitutional states of the system. In the first case, the transformations materially depend on the rapidity with which the exudations are thrown out, or the situation where they occur, and on the vital powers of the body. But in tubercular and cancerous exudations we observe no distinctions from these causes, although it has been remarked that situation so far influences cancer that scirrhus is most common in fibrous, and encephaloma in cellular organs. The more important characters of the three kinds of exudation may be shortly stated as follows :—

We observe in a simple or inflammatory exudation, that it may occur at all epochs in life ; that it may attack all tissues, and most commonly those which are very vascular ; that it may be poured out in large or small quantities ; and that it may occur with greater or less rapidity ; hence the terms *acute* and *chronic.* We further observe, that the acute exudations are generally attended with symptoms of a peculiar character (inflammatory), and have a great tendency to cell or temporary formations, which rapidly break down, are absorbed, and excreted by the emunctories ; that the chronic exudations, on the other hand, have a tendency to fibrous or permanent formations, producing adhesions, strictures, indurations, &c.

We observe in a cancerous exudation that it occurs for the most part in persons of adult or advanced life ; that it may also occur in every tissue, but is by far most common in glandular or fatty organs, such as the liver or female mamma, and is very apt to attack the lymphatic glands *secondarily ;* that its progress, although sometimes slow when very fibrous, becomes rapid when corpuscles abound in it; that there is a great tendency to the formation of the most perfect forms of cell life, which have the power of self-development, and thereby of spreading to neighbouring tissues; and lastly, that when by pressure ulceration is produced on free surfaces, it bursts through these in exuberant fungoid excrescences.

We observe in a tubercular exudation that it occurs for the most part in young subjects, between the periods of dentition and of adult age; that it may also occur in all tissues, but is by far most common *primarily* in the lymphatic glands, and afterwards in fibrous or albuminous textures, as the lungs and serous surfaces; that its progress is in general exceedingly slow; that there is no disposition to the formation of perfect cell formation, but rather to abortive corpuscles, which form slowly, and slowly break down; that there is little tendency to absorption, but great liability to disintegration and ulceration; and finally, that the local changes are almost always preceded by derangement of the *primæ viæ*, and a group of symptoms known under the name of *dyspepsia.*

Taking, then, the products of simple exudation (say pus) as a standard, we cannot fail to remark, that whilst the cell-development of tubercle is below, that of cancer is above this standard. Of the three kinds of exudation, tubercle is the lowest, and cancer the highest, in the scale.

Of the ultimate cause producing this difference in the formative power of the exudation we are ignorant, but every kind of reasoning must lead us to the conclusion, that these changes and effects depend, not upon the vascular system, which is the mere apparatus for the production of exudation; not upon the nervous system, which conducts impressions to or from this apparatus; and not on the texture, which is the seat of the exudation, as that varies, whilst the cancerous or tubercular formation is the same; but in the inherent composition or constitution of the exudation itself. On this point most pathologists are agreed; and hence the supposed existence of various kinds of *dyscrasiæ* originating in the blood, which it is imagined explain the different results produced. But here pathologists pause: once traced back to the blood, they are content; and they have not sufficiently taken into consideration that the blood itself is dependent for its constitution on the results of the primary digestion in the alimentary canal on the one hand, and the secondary digestion in the tissues on the other. Yet it must be evident to every physiologist that if it be the constitution of the blood which determines the nature of the exudation, the causes which produce this must be sought in those circumstances which operate on the composition of the former fluid.

Now, numerous facts render it probable that, while the blood is normal in simple exudation, it contains an excess of nutritive materials in cancerous, and a deficiency of them in tubercular exudation. These are points, however, which can only be established after examining instances of such exudations in detail. But it must not be forgotten, in the meantime, that as the blood is continually undergoing changes, is receiving and giving off new matters, it can scarcely happen that it remains the same for many hours together. An exudation at one time may be very different from that at another. At one period it may abound in elements which do not exist in it at the next. Hence it often happens that a concurrence of circumstances is necessary to occasion a certain result. A cancer, once formed, may remain local until such a series of events arises, comprising, first, the phenomena leading to and producing an exudation; secondly, the occurrence of this exudation in some other tissue or organ sufficiently predisposed for the purpose; and thirdly, a peculiar constitution of the blood. Hence why the histologist is continually finding all kinds of intermediate formations between the three leading kinds of exudation, and why, even when the constitution is thoroughly cancerous or tubercular, simple exudations may be poured into tissues as the result of recent wounds or injuries. But, whilst a recent cancerous or a tubercular exudation may be found to accompany, or alternate with, a simple exudation, the two former are seldom met with together; a circumstance which still further points out the wide difference between the constitutional causes producing them.

The final termination of either kind of exudation may be the same, only each has its peculiarities. We have noticed the tendencies of simple exudation to be transformed into pus or fibres, according to its seat. In the former case, the pus cells break down, and are re-absorbed in a disintegrated and fluid condition into the blood; in the latter, permanent fibrous tissue is produced, constituting chronic adhesions or cicatrices. The cells of a cancerous growth may also degenerate or decay, but this rarely takes place throughout the whole structure. But it is not uncommon to find in certain encephalomatous tumours yellow matter, either in masses or reticulated through its substance (*cancer reticulare* of Müller). This is generally owing to fatty degeneration of the cancer cells. (See "Fatty Degeneration," p. 217.) The fibrous structure of cancer may also increase, and occasionally produce cicatrization. Tubercle possesses no such fibrous stroma; but is infiltrated among the elements of various organs, the vascularity of which it tends to destroy. This, indeed, is the reason why a cancerous tumour increases by growth, which tubercle cannot be said to do; the former is vascular, the latter is not: in the one, cells are formed which have the power of re-development; in the other, no reproductive cells are produced. In cancer, the morbid matter circulating in the blood (whatever that is) is concentrated or attracted to the cancerous part, and should none afterwards be present, the healthy blood is made subservient to the purpose of nourishing a foreign growth. In tubercle, successive fresh exudations only are made, which, by their accumulation, augment the volume or amount of the morbid product.

All three forms of exudation may be rendered abortive by the animal matter being broken down and absorbed, while the mineral matter remains, constituting a cretaceous or calcareous concretion. This is not unfrequently seen as the result of simple exudation; is rare in cancerous, but very common in tubercular exudation.

During the disintegration of simple, cancerous, and tubercular exudations, the animal matter broken down is again rendered fluid, re-passes into the blood, and then constitutes that excess of fibrin detected by chemists. The quantity of this will of course vary according to the amount of the exudation and the activity of the disintegrating process. In the blood this effete matter undergoes a series of chemical changes, preparatory to its excretion by the different emunctories, but more especially by the kidneys, in the form of various sediments. The resolution of simple exudation is generally accompanied by the presence of such urinary sediments, which indicate pretty clearly in what way, after it has passed through the phases of development described, it is at length discharged from the body. In the same manner, the amount of these sediments frequently points out the extent of absorption going on in cancerous and tubercular exudations.

Another theory has been advanced regarding the various products of exudation as we have described them—viz., that instead of being new formations in an exuded blood plasma, they are only modifications of pre-existing texture. According to this view, pus-cells are only altered epithelial ones, cancer-cells are an increased development of gland or other cells, and tubercle corpuscles are a degeneration or "necrosis" of these. This theory, though it has many facts for its support, is opposed by others; so that its fallacy is easily demonstrated. For instance, pus-cells may occur in tissues where no epithelial cells exist, as among muscles, while cancer and tubercle are both found in the white substance of the brain, where there are no cells to develop themselves in the one case, or to degenerate in the other.

Theory of Morbid Growths of Texture.

This comprehends a consideration of the origin, development, propagation, and decline of morbid growths. Doubtless many facts are yet to be discovered as to the structure, chemical composition, and mode of formation of morbid growths; but enough has been ascertained of late years, from combined histological and clinical research, to necessitate great modifications in the views previously held regarding them. The following account, it is only right to say, is derived not only from careful study of what has been written by others, but from a large amount of original investigation.

Origin of Morbid Growths.—All morbid growths consist—1*st*, In augmented development of pre-existing textures (so-called *homologous* or *homeomorphous* growths); 2*d*, Of new elements which have no previous existence in the economy (so-called *heterologous* or *heteromorphous* growths); and 3*d*, Of these two sorts of growth mingled together. The causes which induce them are of two kinds,—1*st*, Local irritation, excited directly or indirectly;

and 2*d*, Constitutional or unknown changes, supposed to operate through the blood. Thus the direct stimulus of a blow may so irritate the tissue of a part as to excite increased nutritive action, so causing hypertrophy, or it may give rise to an exudation; and irritation at a distance may, through the nervous system, produce like effects, as when the female mamma is influenced by the state of the uterus. If, on the other hand, the constitution be affected, such local changes may assume peculiar characters. In this manner, age, sex, hereditary predisposition, and concomitant disorders, as syphilis and cancer, not only modify, but give rise to morbid growths.

It has been a favourite idea with pathologists that morbid growths have fixed tendencies from the beginning, such as are impressed upon the ova of various animals, in virtue of which they are necessarily developed in certain directions. If so, this is not traceable to any peculiarity of structure or chemical composition. In this respect morbid growths are like healthy ones, which, however different in ultimate composition, all originate in a finely molecular blastema. A careful observation of the subsequent development of these growths, however, seems to indicate that specific differences are not impressed upon them from the first—that one does not, as a matter of course, exclude the other, and that any of the classes into which they have been divided may supervene upon preexisting ones. For instance, persons may have a fibrous or glandular growth, and after a time its blood-vessels may pour into it a cancerous exudation, or this latter may undergo a fibrous or fatty transformation. It is only in this manner we can explain numerous cases, which are daily observable in practice, where indolent fibrous tumours suddenly assume increased power of development, and become cancers, or where these last slough out, and subsequently cicatrize.

Besides these constitutional causes, locality and the nature of pre-existing textures have a considerable influence on the formation of morbid growths. Thus, as a general rule, fibrous growths are common in fibrous textures, cartilaginous and bony growths in osseous ones, epithelial growths on epidermic and mucous membranes, and so on. Yet even here the system generally occasions differences. For example, osseous growths in rheumatic constitutions occur at the extremities of long bones; but in syphilitic ones, choose in preference their shafts. In youth, epithelioma occurs in the form of warts on the hands; in syphilitic people it occurs in the genitals; in chimney-sweeps, on the scrotum; in smokers, on the lips, &c. This conjoined influence of constitution and locality indicate the complex causes necessary to produce the results, a study of which is of the greatest moment to the physician, who is desirous, through the former, of operating on the latter, or the contrary, as previously explained in the sketch of the function of nutrition.

Development of Morbid Growths.—All morbid growths, once formed, continue to grow according to the histological laws which regulate development in the textures generally; that is to say, after arriving at a certain point, they attract from the blood-vessels in the neighbourhood, or from such new ones as are formed within themselves, the nutritive materials whereby they augment in bulk. In voluntary muscular fibre, this appears to be accomplished by the fasciculi multiplying fissiparously. In non-voluntary contractile fibre, also, the individual fusiform cells multiply, enlarge, and elongate; a change well observed in the pregnant uterus, in which organ many of the small non-contractile spindle-shaped fibres enlarge, become contractile, and then undergo the fatty degeneration, break down, and ultimately disappear. In the same manner, the elementary parts in hypertrophies of other textures augment fissiparously or endogenously, as in bone and cartilage.

Other forms of morbid growth, especially tumours, are very variable as to rapidity of increase and volume; but the manner in which the development is accomplished is of three distinct kinds:—*1st*, The elementary textures are produced in the same manner as they are in adult tissues. They are either more numerous or larger, but preserve their normal relation and mode of arrangement (*lipoma*, *adenoma*, *angionoma*). *2d*, A matter is thrown out from the blood, which serves as a blastema for the formation of cells, which may be detected in various stages of development, undergoing the same changes that similar textures are seen to present in the embryo (*fibroma*, *osteoma*). *3d*, The cells, whether pre-existing or newly formed, assume such a property of self-multiplication that their normal relation and mode of arrangement is destroyed (*epithelioma*, *enchondroma*, *carcinoma*). These three modes of increase may occur singly or united. Any one or two of them may be superadded to the third, and their occurrence at different times, and in various proportions, accounts to a great extent for the apparent anomalies exhibited in the progress of individual growths.

The third mode of development just alluded to deserves special consideration. It consists of the same kind of endogenous multiplication of cells, with this difference, that sometimes these cells previously existed, whilst at others they have been newly formed in an exudation. Thus the cells in softened cartilage or brain, and those in encephaloma, may be identical; yet the one takes its origin in pre-existing normal cells, whilst the other must arise in the new cells of an exudation, as the white substance of the brain contains no corpuscles from which they could be developed. In the cornea and epithelium similar changes occur, as well as in the bones and mesenteric glands. Yet this lesion, so closely allied in its essential nature, has in these different textures been called by different names, and widely separated pathologically. In the non-vascular cornea and cartilage it has been called *inflammation*, but in the equally non-vascular epithelium it has been named *cancer*. Again, in the vascular bones and glands it has received various names, such as *osteo*, or *medullary sarcoma*, *enlarged glands*, &c.; whilst in the brain and other localities it has been called *encephaloma*, or *soft cancer*. It seems to us that in all these cases the lesion is the same, and that an advanced knowledge of their nature should lead us to group them together. Calling some of them inflammation, and others cancer, supposing the first to be innocent, and the last malignant, is, we contend, incorrect pathology. True theory points out that all these lesions are equally destructive, in consequence of increased endogenous cell growth, and practical experience has long determined the question of their being alike difficult to control.

As a general rule, the greater the number of cells any growth contains, the more rapidly it extends. Hence why a tumour is subject to the laws which govern development and multiplication of cells in addition to those connected with locality and the general powers of the constitution. Thus, room for expansion, and the amount of temperature and moisture, exercise undoubted influence over morbid growths. We see the influence of room for expansion in the cases of adenoma and carcinoma. In adenoma the cells are confined within pouches or ducts. They become crowded on each other; and thus, by means of compression, tend to atrophy and breaking down, rather than to self-multiplication. This is assisted if the distension from within so irritates the fibrous stroma of the gland that it becomes hypertrophied, and occasions a further obstacle to expansion around the seat of cell increase. In carcinoma, we observe that the growth takes place in extent and rapidity proportionally to the number and power of expansion in the cells. If compressed by much fibrous or hard tissue, they multiply slowly; but if an ulceration occurs, say in the skin, then they become developed rapidly, and constitute the so-called soft fungoid excrescences. Heat and moisture, as they are essential to cell growth throughout the animal and vegetable worlds (increased temperature with fluidity favouring, cold and dryness checking it, within certain limits), so the influence of these physical agents may be observed to be equally powerful in morbid growths. Rapid augmentation of a tumour is generally accompanied by increased heat and softening of the parts, whilst colder and harder swellings develop themselves slowly.

Propagation of Morbid Growths.—It has seemed to most pathologists that, while some morbid growths are local, and if removed by the surgeon, do not return, others are constitutional or general, and if cut away, exhibit a great tendency to come back. The former have been called *innocent* or *benignant*, and the latter *malignant*. So far has the notion of malignancy in certain growths been carried, that surgeons have refused to remove them, not because they are inaccessible, or so connected with anatomical parts as to render the operation directly dangerous to life, but simply because they thought the disease was in the blood, and that cutting away the local swelling would either be useless, or give increased activity to the lesion.

But modern research has demonstrated that every kind of morbid growth may be malignant in whatever sense that term be employed, whether used to signify a growth incurable; recurring after the operation or primary lesion; as infiltrating neighbouring or distant tissues and organs; or as continuing its progress and destroying life in spite of all the resources of art. On the other hand, it is easy to prove that all these forms of growth may either disappear spontaneously, or be cured successfully by operation. While, however, we contend that there is no growth which may not be malignant, and none which may not be innocent, it is not denied that some have a greater tendency to spread and affect the system than others. In reference to treatment, therefore, it becomes of the greatest importance to determine the laws which apparently govern the propagation and multiplication of morbid growths, or the circumstances which render—say carcinoma and epithelioma—more susceptible of being communicated to neighbouring and internal organs than purely fibrous or osseous ones.

There is one circumstance which has been overlooked by pathologists, viz., that certain growths abounding in cells have a great disposition to infiltrate themselves among muscles and neighbouring parts, and may be detected there by the microscope, although invisible to the naked eye. In many cases where the surgeon thinks he has removed a morbid growth, he really leaves multitudes of germs behind, which continue to propagate the disease. Hence one of the chief causes of propagation among growths is, that the cells in the process of development become infiltrated among neighbouring tissues. But how do they accomplish this? Van der Kolk suggests that the fluids which they contain mingle with the juice of the parenchymatous substance around them, and that in the latter there are deposited molecules and granules, which, having received from the former certain tendencies to evolution, are ultimately transformed into similar structures. This view is not only exceedingly ingenious but very probable, and will serve to explain how the blood and distant organs are secondarily affected. The notion of solid germs floating in the blood has no facts in its support, but the idea of a fluid secreted by cells being absorbed is consonant with every known law of nutrition.

The fluid, then, of a morbid growth, elaborated in the process of its development, and the result of cell or other formation, would seem to be the most probable material whereby secondary growths are produced. We have seen that many tumours which have no cells may be recurrent, and attack tissues secondarily. Still, they all contain a parenchymatous juice, and as a general rule those that are most soft and pulpy are most liable to return. Many facts, therefore, show that constitutional tendencies do exist for the reproduction of morbid growths similar to those which have previously been formed. A recurrence of all diseases, and espccially of apoplexy, epilepsy, rheumatism, bronchitis, &c., is equally common, and appear to follow the same law. But the idea, that *because* they do so they should be separated under the name of "malignant," appears to us unpathological. Multiplying the numbers of cancers seems equally faulty. We may just as correctly talk of a rheumatism being innocent or malignant, as apply those terms in different cases to fibrous, cartilaginous, osseous, or other kinds of morbid growth, for no other reason than because sometimes they are local, and at others more general.

Decline or Degeneration of Morbid Growths.—In their decline, as in their development, the various kinds of morbid growths follow the laws which regulate degeneration of texture. Some, as lipoma and adenoma, have been known to be gradually absorbed and disappear. Others undergo the albuminous, fatty, mineral, or pigmentary transformations to be subsequently described. To enter into the peculiarities of each morbid growth in this respect would lead us too far. All that need be said here is, that every kind of morbid growth may degenerate, and prove abortive in one way or another. Cancer especially has been known to slough out, and heal by cicatrix, besides having been checked in its development and rendered abortive in every known mode of retrograde transformation.

Theory of Degenerations of Texture.

Degenerations of texture, as previously stated, may be classified into four groups,—viz., the Albuminous, Fatty, Pigmentary, and Mineral degenerations.

Albuminous Degeneration.—It has been previously pointed out that albumen is essential to nutrition, and that it forms the basis of the blood and of the tissues. The flesh which constitutes the food of Carnivora, and the albumen which comprises so large a portion of the fodder of Graminivora, are alike, by the solvent action of the digestive juices, reduced to a fluid state. In this condition it passes into the blood, forming the walls of the blood corpuscles, besides entering largely into the constitution of the *liquor sanguinis* as serum,—that is, albumen dissolved in water. During the building up process of the former it undergoes various transformations, among which those of its conversion into the fibrin of flesh and the gelatine of bones are perhaps the most important. By its association with the other proximate principles also, it enters into the composition of every texture and organ in the body, and again joins the blood as albumen, mixed with a minute portion of effete matter as fibrin. There can be no doubt, as we shall subsequently see, that under certain circumstances it may be changed into fat; and the multitudinous transformations this important element is susceptible of making well merits the term which, in its pure state, Mulder bestowed upon it, namely, that of "proteine."

As albumen, we have seen how it may produce abnormal states of the tissues in various forms. The essential conditions for this kind of degeneration appear to be—1*st*, Extreme slowness of effusion from the blood-vessels, as in cases of chronic tubercle and fibroid transformation; and 2*d*, Mechanical obstruction of the veins in some part of the circulation, giving rise to dropsy. In the former case, it is favoured by excess of acidity in the primæ viæ, which, by its power of dissolving the albuminous compounds, must assist in adding this element to the blood in undue proportion. Why, on the other hand, muscles, cartilage, and the exudations should sometimes pass into the albuminous fibroid degeneration, under pretty much the same circumstances that at others they become fatty, is a point in pathology which is still involved in the utmost obscurity.

Fatty Degeneration.—The causes of fatty degeneration are to be sought in all those circumstances which, while they weaken the vital action of a part, do not interfere materially with the assimilation of hydro-carburets. Yet the disease is not purely local, as it may frequently be observed that the kidneys, liver, heart, and other textures are prone to undergo the fatty change in the same person. Hence everything that increases fatty matter in the blood, such as its introduction by means of assimilation, or its not passing off in consequence of diminished excretion, tends to its production. Thus indulgence in rich food, and alcoholic liquors abounding in carbon, especially if there be little exercise, occasion it. Whether the fatty matter be deposited directly from the blood, or whether it be the subsequent result of a chemical transformation of tissue or exudation, has excited great discussion. Dr Quain supports the latter view, and has performed experiments, whereby it would seem that healthy muscular fibrin may be rendered fatty artificially by digesting it for a fortnight in water. We have repeatedly seen muscles and bones converted into adipocere during the maceration in water necessary to clean the latter, and frequently examined the former during the process, so as to be satisfied that the fibrinous material of flesh undergoes a chemical transformation into fat. We believe with Quain that the same thing occurs in the living body, not only when dead tissues are inclosed in it, as in the experiments of Wagner, but slowly in living texture, until its vigour is at length so impaired that it is incapable of performing its function. This view in no way excludes the probability that in certain cases fatty matter may transude occasionally through the vessels in a fluid state, and collect outside, or be infiltrated to a certain extent among neighbouring textures in a molecular form. Further, we have seen that it may occur within cells as a secretion; and by its accumulation, not only may cause atrophy of the nucleus, but obstruction of tubes, and an endless variety of organic and functional derangements in the economy, according to the extent and seat of the degeneration.

Pigmentary Degeneration.—The formation and modifications of pigment, as observed in plants and animals, is a subject which has been little studied, and opens up a wide field of inquiry for the chemical histologist. But in endeavouring to ascertain the causes which give rise to change of colour in the textures, we may attend to the following circumstances:—

1*st*, Colouring matter bears a certain relation to the non-nitrogenous and oily constituents both in plants and animals. Thus, vegetable oils and resins are seen to form where starch or chlorophyle is collected, and these substances disappear in the cells as the quantity of oil in them increases. In animals we almost always find pigment associated with fat. The brilliant colours of the Invertebrata are so many coloured fats, and the pink fat of the salmon, and green fat of the turtle, indicate the same relation in animals higher in the scale. The epidermic appendages, which are generally coloured, are always covered with fat, secreted by a special apparatus—the sebaceous glands. The blood corpuscles are intimately associated with the chyle, which is an oily emulsion; and the bile is rich in fat. In diseased conditions of the liver, the hepatic cells often contain oil, to the exclusion of the yellow pigment.

2*d*, It would appear that light, heat, and exposure to atmospheric air are connected with the production of pigment. The young leaves of plants are much lighter than those which are older, and the hair of young animals is not so dark as that of the adult. In autumn, the leaves fade, and become brown, reddish, or yellow; and in man, we observe that the pigment of the hair ceases to be formed in advanced age, which at length becomes white. Young fruit is green, and as it ripens the part exposed to the sun is most coloured. Exposure of the skin of man, as is well known, renders it darker; and the fairest skinned individuals (whose integuments are well loaded with fat) are those who are most subject to freckles. Then it must be remembered that while light evolves colour in living, it destroys pigment in dead textures.

Now, the decomposition of the atmosphere is carried on in vegetables by the leaves, under the stimulus of light, and in animals by the lungs and skin. In plants, the leaves fix the carbon and give off the oxygen; in animals the lungs receive oxygen, while carbon is separated in the form of carbonic acid by the same organs, and oxygen in combination with water, in the form of exhalation, is given off both by the lungs and skin. That the skin is connected with respiration is proved by the fact, that if its functions are interrupted, pulmonary diseases, and even asphyxia, are the common results. Carbon is also separated in the form of oily matter largely by the skin and by the liver, an organ also connected with respiration. Hence why Europeans in tropical climates, by breathing a rare atmosphere, eating well, and taking little exercise, are liable to hepatic diseases. Thus the lungs, skin, and liver are intimately associated in the function of excreting carbon; and it is curious that these are the three organs in which pigment is formed. The blood must be brought to the lungs to receive fresh oxygen and give off its carbonic acid, and it is then the white corpuscles of the chyle become coloured, while the blood itself is rendered bright scarlet. On the other hand, the accumulation of carbonic acid in the capillaries communicates the darker tint characteristic of venous blood.

3d, There seems to be a certain connection between the materials introduced into the structure of the plant or animal by means of the soil and of food. Some plants are rich in acids, others in alkalies, or various salts originally derived from the soil, and we have seen that these re-agents operate on colouring matter. Although this subject has been very slightly investigated, we can still perceive how, by the evolution of chemical products acting on different pigments, the various shades of colour may be occasioned which we observe in most plants and some animals at certain seasons. Thus green chlorophyle may be changed in one place into a yellow resin, and in another, by the formation of ulmic or other acids, be transformed to reddish or brown. In animals, the influence of nutrition is traced with more difficulty; but even here we may discern that at certain seasons (such as that of breeding) new products are evolved, which, by operating on the blood or the vital properties of cells, may eliminate more or less colour. According to Hensinger, carbonaceous food used in excess tends to the production of pigment, and hence he explains how the Greenlanders, notwithstanding the cold, are dark coloured from their constant consumption of fat.

Mineral Degeneration.—We have already seen that sometimes this takes place in such a regular manner as to form bone, which replaces the pre-existing texture,—as in muscle, membrane, or certain exudations and tumours. But at others it enters into the constitution of a texture dissolved in fluid, and is thus deposited in or throughout its substance, changing its physical and destroying its vital characters. In this way we separate mineral degenerations from concretions, which are accidental collections in hollow viscera, although undoubtedly they insensibly pass into one another. There is scarcely perhaps any tissue, whether elementary or compound, that may not undergo the mineral degeneration. But it is frequently observed in the coats of blood-vessels more or less associated with atheroma, in exudations, in certain morbid growths—rarely in nervous texture.

All these forms of degeneration may pass into concretions, but are separated from them essentially by being transformations of tissue; while concretions, for the most part, are primary precipitations from fluids.

Theory of Parasitic Growths.

Vegetable Parasites.—It was the demonstration by Bassi in 1837 of the vegetable nature of the disease named *muscardine* in silk-worms, which causes so great a mortality among those animals, which opened up to pathologists a new field for observation, and led to the discovery that certain disorders in the higher animals, and even in man himself, were connected with the growth of parasitic plants of a low type. Schönlein of Berlin was the first to detect them in favus-crusts; and since then they have been found in mentagra, pityriasis, and other diseases of the skin, in various exudations on mucous surfaces, in the stomach of dyspeptics, and in tubercular cavities of the lungs. They belong to the lowest forms of vegetable life, never reaching an organization higher than the Algæ and Fungi. They grow in such portions of diseased animal matter as present certain conditions necessary for their germination, and seldom, if ever, spring from the healthy tissues. Such growths in living animals indicate impairment of the nutritive functions, or diminished vital power in the economy. Hence why they are commonly found in young or scrofulous persons with skin eruptions, and in such as are labouring under prostrating diseases,—as typhus, dysentery, or other epidemic disorders. Numerous efforts to propagate these vegetations in healthy tissues have failed, but if inflammation be excited, or abrasions and sores occasioned, then, by fastening down portions of the fungus, it may be made to grow on the unhealthy parts. Boys at school frequently propagate the disease by wearing each other's caps, or using the same combs. Hence why *favus*, or ringworm, is so difficult to eradicate from charity institutions and extensive schools. The mode of development of these growths is the same essentially as that of most cryptogamic plants, and may be easily seen in any well characterized specimen of favus-crust. This consists of branched thalli, with variable-sized elongated cells, separated by partitions, the terminal ones forming mycelia, with sporules developing within them. Occasionally they present round clusters or chains at the extremity of the branches. The square masses of Sarcina are developed fissiparously.

Animal Parasites enter the body by the food or drink; others as ova, or in some stage of transformation. The mystery which so long enveloped the origin and development of tape-worms is now removed by the labours of modern helminthologists, as has been previously explained under the head of "Reproduction."

DISEASES OF INNERVATION.

The manner in which the different parts of the nervous system have their functions deranged or suspended is only to be understood by paying attention—1*st*, To the pathological laws which seem to govern morbid actions in them; and 2*d*, To the definition of what constitute special nervous diseases, and the general causes producing them. It should be remembered that the encephalon, spinal cord, and nerves consist of an aggregation of organs more or less connected together, the functions of which, especially as regards the different parts of the encephalon, are by no means determined. In health these act in harmony, but in disease they are so irregularly disordered that, while the action of one is excited, that of another may be perverted or annihilated. These derangements of the nervous system are capable of assuming at various times every conceivable disorder of intelligence, sensation, and motion; so that not only may all kinds of diseases which have received names be simulated, but the symptoms may be so curiously combined as to set all arbitrary nosological classifications at defiance. If it be farther remembered that through the brain, spinal cord, and nerves the functions of every organ in the body may be more or less influenced, the endless variety of local as well as of general derangements may perhaps be imagined. Then nothing is more common than to observe some of the most fatal nervous diseases, such as hydrophobia, leaving after death no lesion detectable by the most careful histological examination, whilst on other occasions tumours and extensive destruction of the cerebral mass may exist, without producing any effects whatever. Notwithstanding these difficulties, careful observation, conjoined with a knowledge of physiology, will enable us to approximate closely towards, if not actually reach, a correct view of the disease in the great majority of cases.

GENERAL PATHOLOGY OF THE NERVOUS SYSTEM.

The following are the pathological laws which seem to regulate diseased action of the nervous centres:—

1. *The amount of fluids within the cranium must always be the same so long as its osseous walls are capable of resisting the pressure of the atmosphere.*—That the circulation within the cranium is different from that in other parts of the body was first pointed out by the second Monro. It was tested experimentally by Dr Kellie of Leith, ably illustrated by Dr Abercrombie, and successfully defended by Dr John Reid. The views adopted by these distinguished men were, that the cranium forms a

spherical bony case capable of resisting the atmospheric pressure, the only openings into it being the different foramina by which the vessels, nerves, and spinal cord pass. The encephalon, its membranes and blood-vessels, with perhaps a small portion of the cerebro-spinal fluid, completely fill up the interior of the cranium, so that no substance can be dislodged from it without some equivalent in bulk taking its place. Dr Monro used to point out that a jar or other vessel similar to the cranium, with unyielding walls, if filled with any substance, cannot be emptied without air or some substance taking its place. To use the illustration of Dr Watson, the contents of the cranium are like beer in a barrel, which will not flow out of one opening unless provision be made at the same time that air rushes in. The same kind of reasoning applies to the spinal canal, which, with the interior of the cranium, may be said to constitute one large cavity, incompressible by the atmospheric air.

Before proceeding further, we must draw a distinction between pressure on, and compression of, an organ. Many bodies are capable of sustaining a great amount of pressure without undergoing any sensible decrease in bulk. By compression must be understood that a substance occupies less space from the application of external force, as when we squeeze a sponge, or compress a bladder filled with air. Fluids generally are not absolutely incompressible; yet it requires the weight of one atmosphere, or 15 lb. on the square inch, to produce a diminution equal to $\frac{1}{20000}$th part of the whole. Now, this is so exceedingly small a change upon a mass equal in bulk to the brain as not to be appreciable to our senses. Besides, the pressure on the internal surface of the blood-vessels never exceeds 10 or 12 lb. on the square inch during the most violent exertion; so that, under no possible circumstances can the contents of the cranium be diminished even the $\frac{1}{20000}$th part. When the brain is taken out of the cranium, it may, like a sponge, be compressed by squeezing fluid out of the blood-vessels ; but during life, surrounded as it is by unyielding walls, this is impossible. For let us, with Abercrombie, say that the whole quantity of blood circulating within the cranium is equal to ten,—that is, five in the veins, and five in the arteries; if one of these be increased to six, the other must be diminished to four, so that the same amount, ten, shall always be preserved. It follows, that when fluids are effused, blood extravasated, or tumours grow within the cranium, a corresponding amount of fluid must be pressed out, or of brain absorbed, from the physical impossibility of the cranium holding more matter. At the same time, it must be evident that an increased or diminished amount of pressure may be exerted *on* the brain proportioned to the power of the heart's contraction, the effect of which will be, not to alter the amount of fluids within the cranium, but to cause, using the words of Abercrombie, "a change of circulation" there.

Dr Kellie performed numerous experiments on cats and dogs in order to elucidate this subject. Some of these animals were bled to death by opening the carotid or femoral arteries, others by opening the jugular veins. In some the carotids were first tied, to diminish the quantity of blood sent to the brain, and the jugulars were then opened, with the view of emptying the vessels of the brain to the greatest possible extent; while in others the jugulars were first secured, to prevent as much as possible the return of the blood from the brain, and one of the carotids was then opened. He inferred, from the whole inquiry, which was conducted with extreme care,—"That we cannot, in fact, lessen to any considerable extent the quantity of blood within the cranium by arteriotomy or venesection ; and that when, by profuse hæmorrhages destructive of life, we do succeed in draining the vessels within the cranium of any sensible portion of red blood, there is commonly found an equivalent to this spoliation in the increased circulation or effusion of serum, serving to maintain the plenitude of the cranium."

Dr Kellie made other experiments upon the effects of position immediately after death from strangulation or hanging. He also removed a portion of the unyielding walls of the cranium in some animals by means of trephine, and then bled them to death ; and the differences between the appearances of the brain in these cases, and in those where the cranium was entire, were very great. One of the most remarkable of these differences was its shrunk appearance in those animals in which a portion of the skull was removed, and the air allowed to gravitate upon its inner surface. He says,—" The brain was sensibly depressed below the cranium, and a space left, which was found capable of containing a teaspoonful of water."

It results from these inquiries that there must always be the same amount of fluids within the cranium so long as it is uninjured. In morbid conditions these fluids may be blood, serum, or pus ; but in health, as blood is almost the only fluid present (the cerebro-spinal fluid being very trifling), its quantity can undergo only very slight alterations. There are many circumstances, however, which occasion local congestions in the brain, and consequently unequal pressure on its structure, in which case another portion of its substance must contain less blood, so that the amount of the whole, as to quantity, is always preserved. These circumstances are mental emotions, hæmorrhages, effusions of serum, and morbid growths. Such congestions, or local hyperhemias, in themselves constitute morbid conditions; and nature has to a great extent provided against their occurrence under ordinary circumstances, by the tortuosity of the arteries and the cerebro-spinal fluid, described by Magendie.

Dr Burrows has brought forward several observations and experiments, which he considers opposed to the theory now advocated. His facts are perfectly correct. We have repeated his experiments on rabbits, and can confirm his descriptions. It is the inferences he draws from them that are erroneous. For the paleness which results from hæmorrhage, and the difference observable in the colour of the brain when animals immediately after death are suspended by their ears or by their heels, is explicable by the diminished number of coloured blood particles in the one case, and by their gravitation downwards in the other. That the amount of fluid within the cranium was in no way affected, is proved by the plump appearance of the brains figured by Dr Burrows, and the total absence of that shrunken appearance so well described by Dr Kellie. Neither does our observation of what occurs in asphyxia or apnœa oppose the doctrine in question, as Dr Burrows imagines, but rather confirms it.

On the whole, whether we adopt the terms of local congestion, of change of circulation within the cranium, or of unequal pressure, our explanation of the *pathological* phenomena may be made equally correct, because each of these modes of expression implies pretty much the same thing. But if we imagine that venesection will enable us to diminish the amount of blood in the cerebral vessels, the theory points out that this is impossible, and that the effects of bleeding are explained by the influence produced on the heart, the altered pressure on the brain exercised by its diminished contractions, and the change of circulation within the cranium thereby occasioned.

2. *All the functions of the nervous system may be increased, perverted, or destroyed, according to the degree of stimulus or disease operating on its various parts.*—Thus, as a general rule, it may be said that a slight stimulus produces increased or perverted action, whilst the same stimulus, long continued or much augmented, causes loss of function. All the various stimuli, whether mechanical, chemical, electrical, or psychical, produce the same effects, and in different degrees. Circumstances influencing the heart's action, stimulating drinks or food, act in a like manner. Thus, if we take the effects of alcoholic drink for the purpose of illustration, we observe that, as regards combined movements, a slight amount causes increased vigour and activity in the muscular system. As the stimulus augments in intensity, we see irregular movements occasioned, staggering, and loss of control over the limbs. Lastly, when the stimulus is excessive, there is complete inability to move, and the power of doing so is temporarily annihilated. With regard to sensibility and sensation, we observe cephalalgia, tingling, and heat of skin, *tinnitus aurium*, confusion of vision, *muscæ volitantes*, double sight, and lastly, complete insensibility and coma. As regards intelligence, we observe at first rapid flow of ideas, then confusion of mind, delirium, and, lastly, sopor and perfect unconsciousness. In the same manner, pressure, mechanical irritation, and the various organic diseases, produce augmented, perverted, or diminished function, according to the intensity of the stimulus applied or amount of structure destroyed.

Then it has been shown that excess or diminution of stimulus, too much or too little blood, very violent or very weak cardiac contractions, and plethora or extreme exhaustion, will, so far as the nervous functions are concerned, produce similar alterations of motion, sensation, and intelligence. Excessive hæmorrhage causes muscular weakness, convulsions, and loss of motor power, perversions of all the sensations, and lastly, unconsciousness from syncope. Hence the general strength of the frame cannot be judged of by the nervous symptoms, although the treatment of these will be altogether different, according as the individual is robust or weak, has a full or small pulse, &c. These similar effects on the nervous centres from apparently such opposite exciting causes, can only be explained by the peculiarity of the circulation previously noticed. A change of circulation within the cranium takes place, and whether arterial or venous congestion occurs, pressure on some portion of the organ is equally the result. The importance of paying attention to this point in the treatment must be obvious.

3. *The seat of the disease in the nervous system influences the nature of the phenomena or symptoms produced.*—As a general rule, it may be stated that disease or injury of one side of the encephalon especially influences the opposite side of the body. It is said that some very striking exceptions have occurred to this rule, but these at any rate are remarkably rare. Besides, it is probable that, inasmuch as extensive organic disease, if occurring slowly, may exist without producing symptoms, whilst it is certain most important symptoms may be occasioned without organic disease, even these few exceptional cases are really not opposed to the general law. Then, as a general rule, it may be said that diseases of the brain proper are more especially connected with perversion and alteration of the intelligence; whilst diseases of the cranial portion of the spinal cord and base of the cranium are more particularly evinced by alterations of sensation and motion. In the vertebral portion of the cord, the intensity of pain and of spasm, or want of conducting power, necessary to sensa-

tion and voluntary motion, indicates the amount to which the motor and sensitive fibres are affected. Further than this we can scarcely generalize with prudence.

The fatality of lesions affecting various parts of the nervous centres varies greatly. Thus the hemispheres may be extensively diseased, often without injury to life, or even permanent alteration of function. Convulsions and paralysis are the common results of disease of the ganglia in the cranial portion of the cord. The same results from lesion of the *pons Varolii.* But if the *medulla oblongata,* where the eighth pair originates, be affected, or injury to this centre itself occur, it is almost always immediately fatal.

4. *The rapidity or slowness with which the lesion occurs influences the phenomena or symptoms produced.*—It may be said, as a general rule, that a small lesion—for instance, a small hæmorrhagic extravasation—occurring suddenly, and with force, produces, even in the same situation, more violent effects than a very extensive organic disease which comes on slowly. This, however, will depend much upon the seat of the lesion. Very extraordinary cases are on record where large portions of the nervous centres have been much disorganized without producing anything like such violent symptoms as have been occasioned at other times by a small extravasation in the same place. Here, again, the nature of the circulation within the cranium offers the only explanation, for the encephalon must undergo a certain amount of pressure, if no time be allowed for it to adapt itself to a foreign body; whereas any lesion coming on slowly enables the amount of blood in the vessels to be diminished according to circumstances, whereby pressure is avoided.

5. *The various lesions and injuries of the nervous system produce phenomena similar in kind.*—The injuries which may be inflicted on the nervous system, as well as the morbid appearances discovered after death, are various. For instance, there may be an extravasation of blood, exudation of lymph, a softening, a cancerous tumour, or tubercular deposit, and yet they give rise to the same nervous phenomena, and are modified only by the circumstances formerly mentioned, of degree, seat, suddenness, &c. Certain nervous phenomena also are of a paroxysmal character, whilst the lesions supposed to occasion them are stationary or slowly increasing. It follows that the effects cannot be ascribed to the nature of the lesions, but to something which they all have in common; and this apparently may consist of—1*st*, Pressure, with or without organic change; 2*d*, More or less destruction or disorganization of nervous texture. Further, when we consider that the same nervous symptoms arise from irregularities in the circulation; from increased as well as diminished action; sometimes when no appreciable change is found, as well as when disorganization has occurred; the theory of local congestions to explain functional alterations of the nervous centres seems the most consistent with known facts. That such local congestions do frequently occur during life without leaving traces detectable after death, is certain; whilst the occurrence of molecular changes, or other hypothetical conditions which have been supposed to exist, have never yet been shown to take place under any circumstances.

SPECIAL PATHOLOGY OF THE NERVOUS SYSTEM.

The special disorders of the nervous system may be classified into—1*st*, Cerebral; 2*d*, Spinal; 3d, Cerebro-spinal; 4*th*, Neural; and 5*th*, Neuro-spinal; according as the brain.

spinal cord, or nerves are affected alone, or in combination. Aberrations of intellect always depend on cerebral disturbance, while perversions of motion and sensibility, if extensive, indicate spinal, and if local, neural disorder. Thus, insanity and apoplexy are cerebral; tetanus and chorea, spinal; epilepsy and catalepsy are cerebro-spinal; neuralgia and local paralysis are neural; and all combined spasms, dependent on diastaltic or reflex actions, are neuro-spinal. The following is an enumeration of nervous disorders, with the meanings that ought to be attached to them.

Classification of Diseases of Innervation.

I. *Cerebral Disorders, in which the cerebral lobes (or brain proper) are affected :—*

INSANITY, or mental aberration in its various forms, including *delirium.*

HEADACHE and other uneasy sensations within the cranium, such as lightness, heaviness, vertigo, &c. &c.

APOPLEXY.—Sudden loss of consciousness and of voluntary motion, commencing in the brain. The absence of consciousness necessarily involves that of sensation. The same condition as regards nervous phenomena exists in *syncope* and *asphyxia*, but the first of these commences in the heart, and the second in the lungs. Allied to apoplexy is coma or stupor, arising from various causes affecting the brain, such as pressure, or poisonous agents like alcohol, chloroform, opium, &c. &c.

TRANCE, or prolonged somnolence, either with or without perversion of sensation or motion. To this state is allied *ecstasy*, or unconsciousness with mental excitement.

IRREGULAR MOTIONS, SPASMS, &c., originating in excited or diminished voluntary power, as in certain cases of *dominant ideas, somnambulism, saltatory movements, tre-*

mors, &c.; or, on the other hand, *incapability of movement* from langour, surprise, mental agitation, &c. &c.

II. *Spinal Disorders, in which the cranial and vertebral portions of the spinal cord are affected:—*

Spinal Irritation.—Pain in the spinal column, induced or increased by pressure or percussion, often associated with a variety of neuralgic, convulsive, spasmodic, or paralytic disorders affecting in different cases all the organs and viscera of the body, and so giving rise to an endless number of morbid states.

Tetanus.—Tonic contraction of the voluntary muscles. *Trismus*, if confined to the muscles of the jaw; *Opisthotonos*, if affecting the muscles of the back, so as to draw the body backwards; *Emprosthotonos*, if affecting the muscles of the neck and abdomen, so as to draw the body forwards; and *Pleurosthotonos*, if affecting the muscles of the body laterally, so as to draw the body sideways.

Chorea.—Irregular action of the voluntary muscles, when stimulated by the will.

Hysteria.—Any kind of perverted nervous function, connected with uterine derangement. Nothing can be more vague than this term.

Hydrophobia.—Spasms of the muscles of the pharnyx and chest, with difficulty in drinking and dread of fluids.

Spasms and Convulsions.—Tonic and clonic contractions of the muscles of every kind and degree, not included in the above, originating in the cord (centric spinal diseases —Marshall Hall).

Hemiplegia.—Paralysis of a lateral half of the body, generally dependent on disorders of the cranial portion of the spinal cord above the decussation in the *medulla oblongata*.

Paraplegia.—Paralysis on both sides of the body, generally the lower half, in consequence of disorder of the vertebral portion of the spinal cord, below the decussation in the *medulla oblongata.*

III. *Cerebro-Spinal Disorders, in which both cerebral lobes and spinal cord are affected :—*

EPILEPSY.—Loss of consciousness with spasms or convulsions occurring in paroxysms. *Apoplexy with convulsion or paralysis* is also cerebro-spinal.

CATALEPSY.—Loss of consciousness with peculiar rigidity of muscles, so that when the body or a limb is placed in any position it becomes fixed.

ECLAMPSIA.—Tonic spasms with loss of consciousness in infants. The acute epilepsy of some writers.

IV. *Neural Disorders, in which the nerves are affected during their course or at their extremities :—*

NEURALGIA.—Pain in the course of a nerve, although in fact all kind of pain whatever is owing to irritation of the nerves. Thus the sympathetic system of nerves and its ganglia, though ordinarily giving rise to no sensation, may occasionally do so, as in *angina pectoris, colic, irritable testicle and uterus,* and in other agonizing sensations, referred to various organs.

IRRITATION OF THE NERVES OF SPECIAL SENSE.—Of the optic, causing *flashes of light, ocular spectra, muscæ volitantes,* &c.; of the auditory, causing *tinnitus aurium ;* of the olfactory, causing unusual *sensitiveness to odour ;* and of the gustatory, causing *perverted tastes* in the mouth. Itching, formication, and other sensations referable to the peripheral nerves, also belong to this class.

IRRITATION OF SPECIAL NERVES OF MOTION, as in local spasms of one or more muscles, or of the hollow viscera.

LOCAL PARALYSIS.—Loss of motion or sensibility in a limited part of the body, or confined to a special sense, as in *lead palsy*, or in *amaurosis*, *cophosis*, *anosmia*, *ageustia*, and *anæsthesia*.

V. *Neuro-Spinal Disorders, in which both the nerves and spinal cord are affected:—*

DIASTALTIC OR REFLEX ACTIONS.—To this class belong all those diseases depending on irritation of the extremity of a sensitive nerve, acting *through* the cord and motor nerves on the muscular system, and producing a variety of spasmodic disorders, local or general, far too numerous to mention,—which can only be understood by a thorough knowledge of the physiology of the diastaltic or excito-motory system of nerves.

All these disorders may be the result of structural disease of the nervous system, or of what is called *functional derangement*, understanding by this a disease which, even when it causes death, leaves no trace of altered structure detectable with the aid of the microscope. Thus, tetanic rigidity may depend on a spinal arachnitis, as well as on the irritation from a wound or poisoning by strychnine; and delirium and coma may be caused by cerebral meningitis, as well as by moral insanity, starvation, or poisoning by chloroform or opium. Whether in these cases there be in fact only one cause common to the whole, it is difficult to say; certainly it cannot be demonstrated. It might be contended that in every instance there is a certain amount of congestion producing unaccustomed pressure, or that a peculiar state of nutrition of the part is momentarily produced here or there in the nervous mass. But as neither theory appears to us applicable to all cases, we shall consider the pathological causes of nervous disorders as of four kinds,—1*st*, Congestive; 2*d*, Structural; 3*d*, Diastaltic; 4*th*, Toxic.

1. *Congestive Deranjements of the Nervous System.*—The peculiar nature of the circulation within the cranium and vertebral canal has been previously pointed out, and we have seen that, although well defended under ordinary circumstances against any mischievous change, still, when such change does occur, it operates in a peculiar manner. In other words, so long as the bones are capable of resisting atmospheric pressure, although the amount of fluid within these cavities cannot change as a whole, yet the distribution of that amount may vary infinitely. Thus, by its being accumulated sometimes in the arteries, at other times in the veins, or now in one place and then in another, unaccustomed pressure may be exercised on different parts of the nervous centres. This, according to its amount, may either irritate or suspend the functions of the parts; a fact proved by direct experiment, as well as by innumerable instances where depression of bone has caused nervous phenomena which have disappeared on removal of the exciting cause. That congestion does frequently occur in the brain and spinal cord there can be no doubt, although it cannot always be demonstrated after death. The tonic contraction of the arteries is alone sufficient to empty them of their contents, and turgidity of the veins may or may not remain according to the symptoms immediately preceding death, and the position in which the body is placed. But it is observable that those causes which excite or diminish the action of the heart and general powers of the body are at the same time those which induce nervous disturbance, as well as occasion a change of circulation in the cerebro-spinal centres—such as the emotions and pas-

sions, plethora and anæmia, unaccustomed stimuli, uterine derangement, &c.

It is only by this theory that we can understand how such various results occasionally occur from apparently the same cause, and again how what appear to be different causes produce similar effects. Thus, violent anger, or an unaccustomed stimulus may, in a healthy person, induce a flushed countenance, increased action of the heart, a bounding pulse, and sudden loss of consciousness. Again, fear or exhaustion may occasion a pallid face, depressed or scarcely perceptible heart action, feeble pulse, and also loss of consciousness. In the first case, or *coma*, there is an accumulation of blood in the arteries and arterial capillaries, and a corresponding compression of the veins ; in the second case, or *syncope*, there is distension of the veins and venous capillaries, with proportionate diminution of the calibre of the arteries. In either case, owing to the peculiarity of the circulation within the cranium, pressure is exerted on the brain. Hence syncope differs from coma only in the extreme feebleness of the heart's action,—the cause, producing loss of consciousness, sensation, and voluntary motion, being the same in both. Indeed it is sometimes difficult to distinguish these states from each other ; and that they have frequently been confounded, does not admit of doubt.

In the same manner, partial congestion from either cause may occur in one hemisphere, or part of a hemisphere, in the brain, or in any particular portion or segment of the spinal cord. The pressure so occasioned may irritate and excite function, or may paralyse or suspend it ; nay, it may so operate as to suspend the function of one part of the nervous system, while it exalts that of another. Thus all the phenomena of epilepsy are eminently congestive, the individual frequently enjoying the most perfect health in the intervals of the attack, although the effects are for the time terrible, causing such pressure that, while the cerebral functions are for the time annihilated, the spinal ones are violently excited. In the same manner are explained all the varied phenomena of hysteria and spinal irritation, for inasmuch as the spinal cord furnishes, directly or indirectly, nerves to every organ of the body, so congestion of this or that portion of it may increase, pervert, or diminish the functions of the nerves it gives off, and the organs which they supply. Congestion, therefore, we conceive to be the chief cause of functional nervous disorders originating in the great cerebro-spinal centre.

2. *Structural Derangements of the Nervous System.*—The various parts of the nervous system, being furnished with blood-vessels, are subject to most of the diseases of nutrition. The brain and spinal cord are especially liable to those lesions which produce effusion, extravasation, exudation, morbid growths, and degenerations of texture. The effects these occasion are identically the same in kind as those caused by simple pressure, or from the other circumstances to be referred to. In their mode of onset, however, they exhibit a difference. Thus, as a general rule, hæmorrhage is indicated by suddenness of attack, acute exudations, by local pain, with fever, chronic exudations and tumours, by gradual perversion of the mental, sensitive, and motor functions in various ways and degrees, according to the part affected. Intelligence suffers in proportion to the extent and nearness of the disease to the hemispherical ganglion, and motion according as the cerebral and vertebral portions of the spinal cord are influenced. Occasionally, after more or less impairment of intellect, sudden paralysis appears; a result attributable to the rupture or deliquescence of tubes which have been already

softened, but not sufficiently so to interrupt their power as conductors of the nervous force. Instances, indeed, have been recorded where complete destruction of one half of the brain, or of the whole thickness of the spinal cord, is said to have occurred, in which no paralysis or other symptom has been caused; but it is certain that numerous tubes in such cases were intact during life, and capable of transmitting impressions.

3. *Diastaltic or Reflex Derangements of the Nervous System.*—We have previously seen that recent researches render it probable that the actions hitherto denominated *reflex* are in fact direct; only that the impression which is conveyed commences in the circumference of the body, instead of in the nervous centres. There is every reason to believe that such impressions pass *through* the cord by means of conducting nerve fibres, which cross from one side of that organ to the other, and that histology will yet demonstrate that all these apparently confused actions are dependent on the existence of certain uniform conducting media. Indeed, already we can judge with tolerable exactitude from the effects, what are the particular nerves and segments of the cord which are influenced during a variety of actions; and notwithstanding the immense difficulties of the inquiry, we have every hope that the period is not distant when the diagnosis of many more reflex acts will also be rendered certain. The principle involved in all these acts is, that the irritation which produces them is to be sought for in the nervous extremities rather than in lesions of the centres; and the great importance of this principle in pathology and in practice cannot be too highly estimated, although, for the numerous details which illustrate it, we must refer to a previous part of this book, and especially to the works of Dr Marshall Hall. We would

point to traumatic tetanus, and to the convulsions resulting from teething and gastric derangements in children, as good examples of diastaltic functional disorders. Numerous symptoms which accompany organic changes belong to the same category. In other words, the structural lesion constitutes the irritant, or cause, while the effect is functional.

4. *Toxic Derangements of the Nervous System.*—The influence exercised by certain drugs is of a kind which causes a close resemblance to various diseases of the nervous system. These influences, if carried to excess, are toxic, and dangerous to life; if employed moderately, and with caution, they constitute the basis of our therapeutic knowledge in a vast variety of diseases. Why one drug should possess one power, and another a different one; or why some should influence the brain, and others the spinal cord or nerves, we are ignorant. Such facts are as much ultimate facts in therapeutics as are the separate endowments of contractility and sensibility in physiology. As pathological causes of functional disorders of the nervous system, their power is undoubted. By their means the five classes of nervous disorders may be occasioned in different ways, producing altogether distinct and peculiar effects. Thus—

Toxic Cerebral Derangements are occasioned by opium and most of the pure narcotics, which first excite and then depress or destroy the mental faculties. According to Flourens, opium acts on the cerebral lobes, while belladonna operates on the *corpora quadrigemina.* The first causes contraction, and the last dilatation of the pupils. *Tea* and *coffee* are pure excitors of the cerebral functions, and cause sleeplessness. *Alcoholic drinks*, *æther*, *chloroform*, and similar stimulants, first excite and then suspend the mental faculties, like opium. The modern practice of depriving persons of consciousness, in order for a time to destroy sensation, has been very much misunderstood in consequence of such remedies having been erroneously and unscientifically denominated anæsthetics. The fact is, they in no way influence local sensibility, or the sense of touch. Their action is altogether cerebral; and hence the danger which has frequently attended their action.

Toxic Spinal Derangements.—*Strychnine* acts especially as an excitor of the motor filaments of the spinal cord, causing tonic muscular contractions, as in tetanus from spinal arachnitis, or from the diastaltic action of a wound. *Woorari* produces exactly an opposite effect, causing paralysis and resolution of the same parts. *Conium* paralyses the motor and sensitive spinal nerves, producing paraplegia, commencing at the feet, and creeping upwards. *Picrotoxine*, according to Dr Mortimer Glover, causes the animal to stagger backwards, as in the experiments of Magendie on the *crura cerebelli.*

Toxic Cerebro-Spinal Derangements.—Of these, the poisonous effects of hydrocyanic acid offer a good example. All the animals we have seen killed by this agent utter a scream, lose their consciousness, and are convulsed. These are the symptoms of epilepsy. *Cold* is at first an excitor of the spinal functions, and is a strong stimulant to diastaltic activity, but if long continued, produces drowsiness and stupor.

Toxic Neural and Neuro-Spinal Derangements are especially occasioned by the action of certain metallic poisons, such as *mercury*, which occasions irregular muscular action, with weakness; and *lead*, which causes numbness and palsy, most common in the hands. On the other hand, *cantharides* stimulates the contractions of the neck of the urinary bladder, and *secale Sornutum* those of the pregnant uterus. *Stramonium* acts as a sedative to the nerves of the bronchi; while *aconite* operates powerfully in paralysing the action of the heart.

DISEASES OF REPRODUCTION.

These consist in the various alterations which may occur in the different stages of the generative functions, and include,—1*st*, Diseases which arrest or modify ovulation; 2*d*, Diseases, nutritive or nervous, which impede fecundation, and occasion barrenness in the female, or impotence in the male; 3*d*, Diseases of the embryo, causing various kinds of monsters, from arrest or excess of development in one or more of its parts. This last subject is now generally studied under the name of *teratology* (τέρας, *monster*), and has in recent times become a very extensive one. Congenital malformations of the fœtus were formerly considered as indicative of some misfortune,—as the effect of witchcraft, or as offsprings of the evil spirit. They are now not only recognised to originate in natural derangements of embryonal development, but the laws which govern such derangements have to a great extent been determined. From these it has become evident that monstrosities are not the result of chance, but are always regulated by alterations in the known processes which regulate reproduction, and the evolution of the ovum and its contents. Hence in this, as in every other disordered condition, the real source of the abnormality is to be sought for, not only in the investigation of that condition itself, but in the knowledge, first, of the healthy or physiological state; and secondly, of the manner in which it has become deranged.

In all our inquiries, it must be apparent that disease is morbid physiology; and such is the aspect in which we have endeavoured to place it before the reader.

ON DEATH.

Death is the permanent cessation of those properties and functions which constitute life. In this wide sense, it must be apparent that the textures are continually dying, in the same manner that they are continually being generated. What we have described as the fourth stage of nutrition essentially consists in the removal of the particles of the body which have been worn out,—fulfilled their functions, and died. Thus, death is molecular, cellular, fibrous, or tubular, in proportion as these various organic elements become degenerated, and disappear to make way for others which enjoy activity or life, and in their turn die, enter into new chemical combinations, and are excreted like their predecessors. In the more common acceptation of the term, however, death may be considered as *partial* or *general*. Partial death of the animal body is caused by those diseases or injuries which produce mortification, and ulceration in soft, and necrosis and caries in the hard parts, to a greater or less extent. Of this we have already spoken, and therefore need only treat of general death of the system. This has been variously considered as *natural* or *unnatural;* by the former meaning death from old age or gradual decay, and by the latter, death from diseases or violence. In this latter case, death may be gradual or sudden, and be induced by a great variety of agents. It may be said, however, that all the modes of death are reducible to three, viz.,—1*st*, Death by syncope,—that is, beginning at the heart; 2*d*, Death by asphyxia, beginning at the lungs; and 3*d*, Death by coma, beginning at the brain.

Death by Syncope.—All causes which arrest the action of the heart occasion stoppage of the circulation; a circumstance which interferes with the due performance of the vital functions; and death is the consequence. It may occur through the nervous system, through feebleness of the muscular walls of the heart itself, or through loss of blood. As examples of the first method of causing syncope, may be cited concussion, or all sudden shocks to the system,—as from violent blows or injuries, extensive lesions, violent mental emotions, a stroke of lightning, exposure to the sun (or *coup de soleil*), and certain poisons which, acting especially on nerves going to the heart, paralyse its rhythmical motions, as aconite, digitalis, &c. Syncope from feebleness of the muscular walls is illustrated by the effects of long-continued violent exertion, starvation, and disease of its textures, especially that now recognised as fatty degeneration, one of the most common causes of sudden death. Lastly, excessive loss of blood, whether from direct external injury to a large vessel, sudden bursting of an internal vascular tumour or aneurism, disease of the coats of an artery or vein leading to sudden or to long-continued loss of blood, are among the frequent causes of syncope.

Death by Asphyxia.—This is produced by all causes which interrupt the act of respiration, or the access of oxygen, so necessary for carrying on the nutritive functions, and has been previously referred to. It is now ascertained that mere obstruction of air does not immediately act upon the heart, which not only continues to contract for a time, but even sends venous blood through the arterial system. From the numerous investigations which have been made to determine in what manner the vital actions are arrested in asphyxia, it would appear that at first non-aërated or venous blood passes freely through the lungs to the heart, from whence it goes to all parts of the system. It operates on the brain, however, as a poison, rapidly suspending the sensorial functions. The capillaries of the lung next refuse to transmit non-oxygenated blood, in consequence of which it is not returned to the right side of the heart, and thus the vital actions cease. These effects are produced with greater or less rapidity, according as the occlusion of air is more perfect, as in cases of drowning and strangulation. In diseases of the heart and lungs, the same results are produced more slowly. The only poisons which operate upon the lungs directly causing asphyxia are certain so-called poisonous gases, such as carbonic acid gas, the fatal effects of which, however, are not so much to be ascribed to any noxious properties it possesses, as to the absence of free oxygen.

Death by Coma.—This is caused by all circumstances which suspend the sensorial functions by first operating on the brain. We observe it produced from the long-continued action of cold, from the influence of narcotic poisons, especially opium and chloroform, and from such injuries of the brain, from without or within, as are not necessarily connected with shock. If a violent blow be given to the head of an animal, it may be observed to suffer from shock or syncope; the heart flutters, and the pulse is weak. But if it recover from this, the heart's action may be restored, whilst sensation is suspended, and it dies comatose. If shock be avoided during the operation, the brain of an animal may be removed, producing coma or stupefaction, which will ultimately kill, although for some time the circulation and respiration continue. In apoplexies, fevers, and other diseases, similar effects are observable.

It should not be overlooked that death in many cases is produced by a conjunction, or by the rapidly-following results of two or all three of these modes. Thus chloroform may kill from the conjoined stupefying action on the brain, as well as from difficulty of respiration. Coma, from pressure on the brain, may, by influencing the *medulla oblongata*, affect the pneumo-gastric nerves, which send branches to the heart and lungs. In this case, death is the most rapid—occurring in all three ways. Hence the humane effort of the hangman not only to produce strangulation, but by dislocation of the bones of the neck to crush the upper part of the spinal cord.

The preceding observations evidently indicate that, in our endeavours to produce recovery from either of these states, much will depend upon the correct information we derive as to the causes producing them. In syncope, our efforts will be directed to restore the action of the heart by stimuli, a proper position, checking hæmorrhage, &c.; in asphyxia, to reproduce respiration ; and in coma, to remove any cause which, by pressure on the brain from without or within, interferes with its functions.

THE END.

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